COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

June 1959

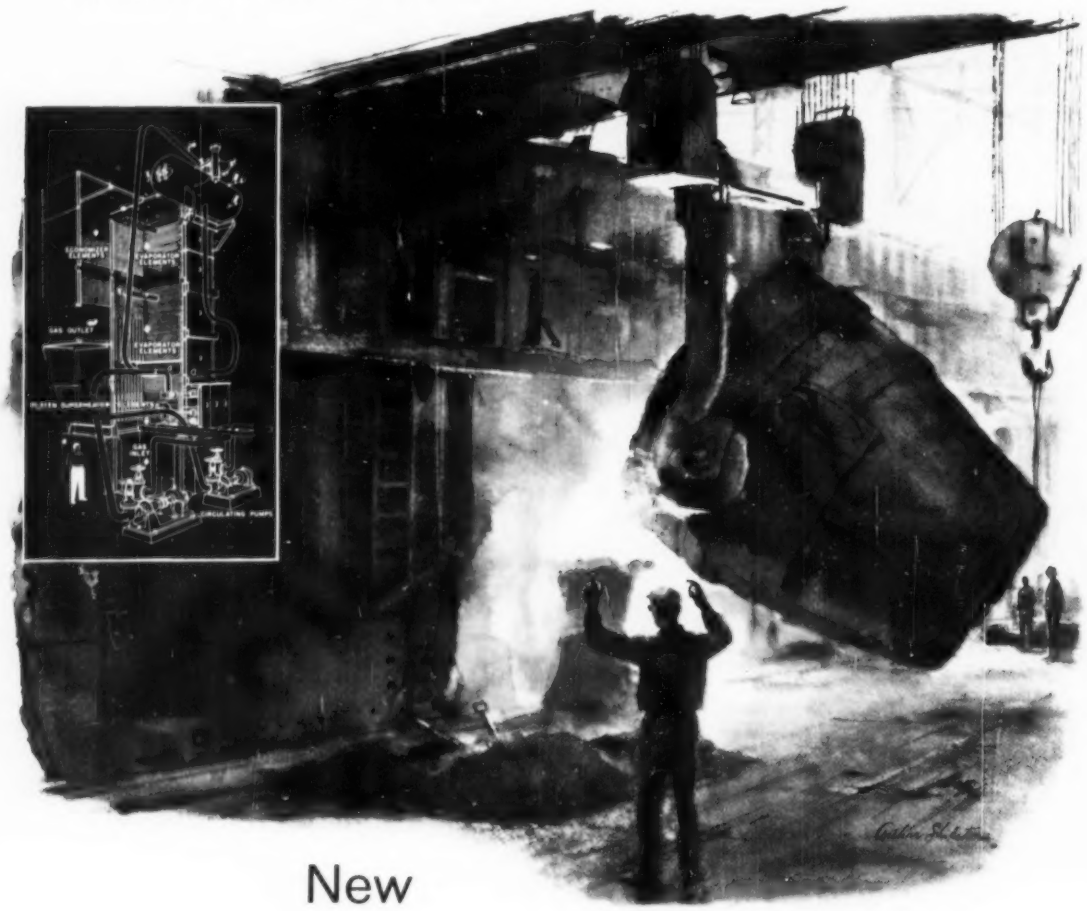
37-ft high stainless-steel reactor vessel, the heart of the Enrico Fermi Atomic Power Plant.

Gas Recirculation

American Power Conference

Power Plant Clinic

"CREATIVE ENGINEERING" GUIDES STEEL MILL WASTE HEAT INTO MORE PRODUCTIVE CHANNELS



New "Package" Boiler squeezes more steam out of by-product BTU's

The open hearth furnaces of a steel mill produce large quantities of very hot gas. Frequently, this heat-laden gas is used to generate steam for the mill by passing it through "fire tube" boilers. But the limitations inherent in this type of boiler prompted Combustion—an organization with more than 75 years of experience in harnessing heat—to develop a new boiler concept to better meet this special need.

The result is the C-E Waste Heat Boiler, Type WCC, a completely shop-assembled (package) unit. Its unique feature is the use of "Controlled Circulation," as developed by C-E for large utility boilers and now generally regarded as the most important development of this decade in the field of steam generation. This feature enables the WCC Boiler to produce substantially greater amounts of steam from the same volume of waste gases. The WCC Boiler is expressly designed to handle "sticky" or abrasive gases without erosion, and with minimum maintenance. It therefore promises important advantages for many applications outside the steel industry—notably, in the chemical process industries.

Here then is another example of **C**reative **E**ngineering—the C-E approach to providing the most advanced designs of boilers for all fuels and steam requirements—from those of small industrial and institutional plants to the largest utility power stations.

"CREATIVE ENGINEERING" is the reason for the leadership attained by C-E products. The products which bear this mark of leadership include:

all types of steam generating, fuel burning and related equipment • nuclear power systems • paper mill equipment • pulverizers • flash drying systems • pressure vessels • soil pipe

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

C-2716

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 30 **No. 12**

June 1959

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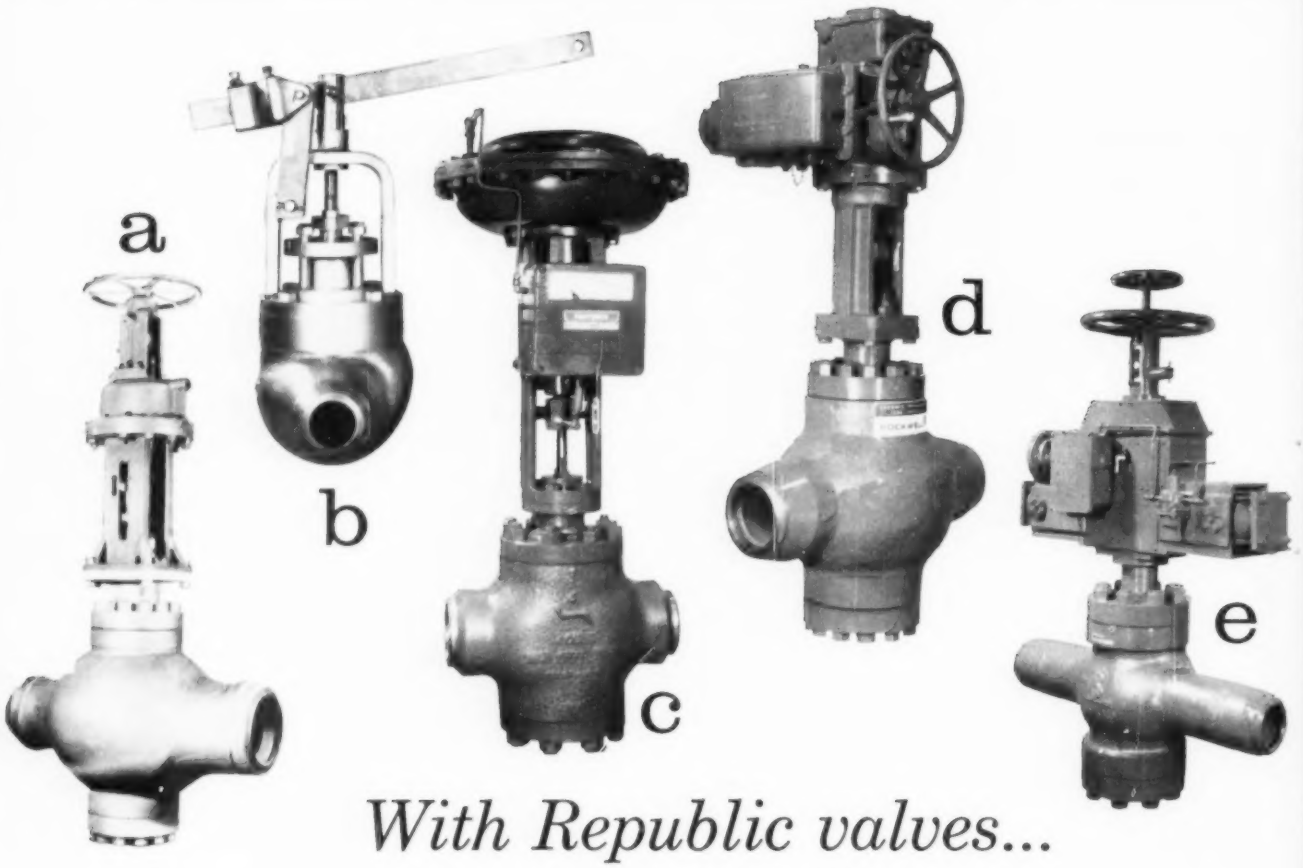


With Republic valves...

You get longer life, less maintenance

For over 35 years Republic valve developments have paced the changing demands for more sturdy valves by the most progressive utilities and industries. For such services as pump recirculation control, feedwater regulation, steam pressure reducing and high pressure water control, Republic valves have established a reputation for durability, long life and trouble-free performance.

Superior valve design—Republic research into the causes of valve noise and vibration, and also the wear resisting and galling properties of materials has resulted in a modern line of Republic valves of advanced design. Republic valve contours are designed to produce not only the desired regulating characteristics but also to reduce erosion damage and noise as well. Extra large guide bushings, extra deep stuffing boxes, solid plug inner valve construction, plus precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance.

Wide selection of valves and features—Rockwell-built Republic regulating valves shown on this page are representative of the complete Republic line:

a. **Cylinder operated valve**
b. **Lever operated valve**
c. **Diaphragm operated valve**
d. **Motor operated valve**
e. **Toggle head operated valve**
f. **Diaphragm operated angle valve**

And, for many special applications, such Republic accessories as pneumatic and electric valve positioners for hysteresis-free control, and a complete line of controllers are available.

Whatever your regulating valve problem, let Republic engineers put their years of application experience to work for you. For additional information, see your Republic representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois.

REPUBLIC INSTRUMENTS AND CONTROLS

more fine products by

ROCKWELL

72 tons of *FLY ASH* collected a day!

GREEN'S AERODYNE HELPS SOLVE CONSOLIDATED EDISON'S FLY ASH PROBLEM

Installation of Aerodyne Units at Consolidated Edison's Hell Gate Electric Generating Station.

Green makes this AERODYNE mechanical dust collector, to collect fly ash and other dusts. Does this Green AERODYNE really work?

Well, let's quote a few words from Mr. J. J. Grob, Chief Performance Engineer, Mechanical Engineering Department, Consolidated Edison Company of New York, Inc.

QUOTE 1
Why used . . . . . "At Hell Gate Station two Aerodyne mechanical collectors were installed in the uptake flues of boilers No. 11 and 12 for removing the bulk of fly ash leaving the furnaces."

QUOTE 2
72 tons of fly ash per day . . . . . "The furnaces are slag tap and, of that ash which would otherwise be expelled to the electrostatic precipitators before entering the stack, the Aerodyne units, based on careful tests, remove approximately 72 tons of fly ash per day."

QUOTE 3
Satisfactory . . . . . "The operation of the Aerodyne mechanical collectors has been satisfactory and the life of the cones has greatly exceeded expectations."

We repeat, in all modesty — Green can help you solve FLY ASH and DUST collection problems.

Why not write and ask us?

Green

THE GREEN FUEL ECONOMIZER CO., INC. BEACON 3, NEW YORK

predictable, dependable performance...

Republic ELECTRUNITE Boiler Tubing offers Quality you can measure

Predictable, dependable Republic ELECTRUNITE® Boiler Tubes were used in the installation of a new power plant unit for the production of electricity for the Borough of Lansdale, Pennsylvania.

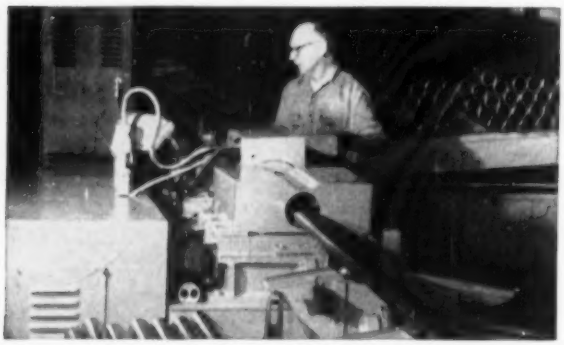
This new steam generator, engineered, manufactured, and erected by Riley Stoker Corporation, Worcester, Massachusetts, is designed to operate at 150,000 pounds of steam per hour, 1000 psi, at a steam temperature of 900° F.

Predictable . . . because ELECTRUNITE Boiler Tubing is hydrostatically or electronically tested to conform with the applicable ASTM specifications and the ASME Boiler and Pressure Code, as well as local, state, and boiler insurance requirements.

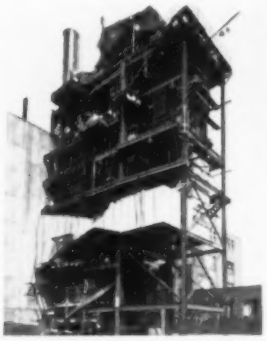
Dependable . . . because ELECTRUNITE Boiler Tubes are made from high-grade steel, produced in Republic's own mills. Operations, materials, and methods are carefully controlled from the time the ore is mined, through mill, and manufacturing processes.

Performance . . . proved on the job, job-after-job. Skilled craftsmen on the job report, "with ELECTRUNITE, the rolling goes well . . . the metal works properly, rolls in smoothly . . . we never worry about cracks in the tubing."

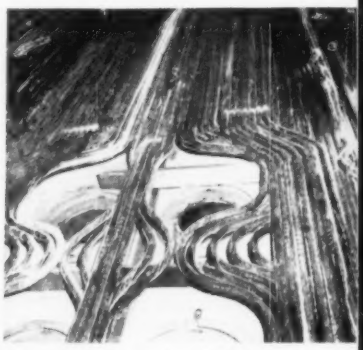
Get the facts. Learn more about Republic ELECTRUNITE for boiler, heat exchanger, condenser, evaporator applications. Call your Republic representative. Or, write direct.



FARROWTEST®—QUALITY YOU CAN MEASURE. Not a laboratory theory, not a mere inspection tool, but an exclusive production test that detects and rejects tubing containing defects of critical size. FARROWTEST is offered as an alternative to other less positive tests in accordance with table below, at no extra cost.



Power plant at Borough of Lansdale does not have a grate surface. Instead, powdered coal fuel which burns in suspension is fed in through water-cooled ports on front wall.

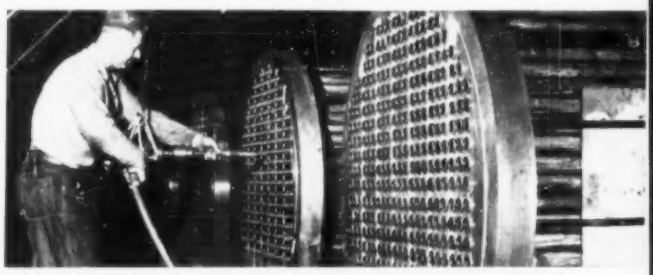


Full normalizing makes Republic ELECTRUNITE uniformly ductile for smooth, easy bending, trouble-free service. This view shows the fuel ports from the inside.

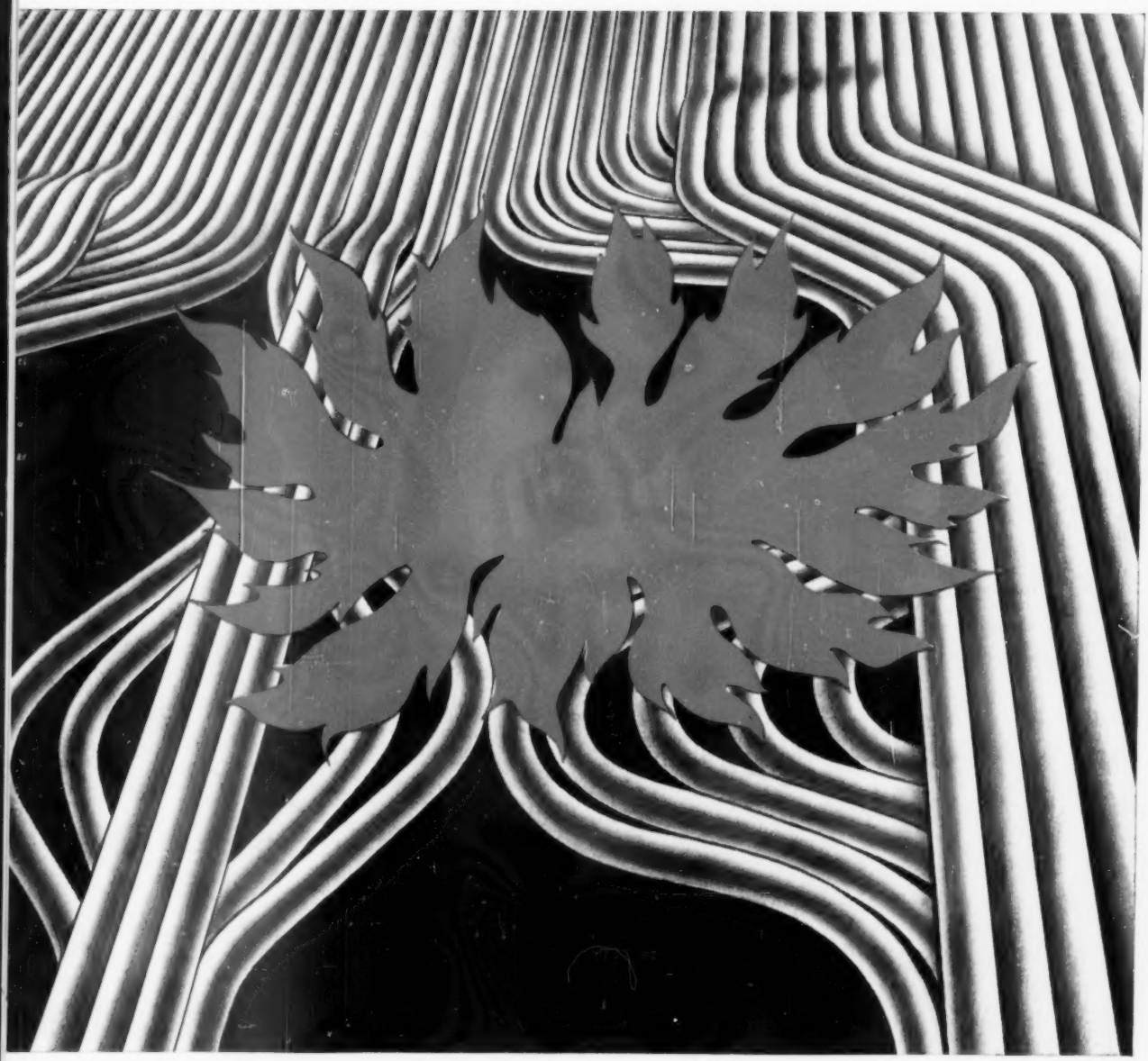
FARROWTEST REJECT TABLE

Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.



More and more engineers in utility companies are considering Republic ELECTRUNITE Stainless Steel Tubing for main surface condensers. Republic's ELECTRUNITE Stainless Steel resists corrosion, provides long, trouble-free service where water is used directly from natural sources. Call your local Republic ELECTRUNITE representative, or write for facts and data.



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World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
STEEL AND TUBES DIVISION
DEPT. C-7911
209 EAST 131st STREET • CLEVELAND 8, OHIO

Please send more information on the following products:

☐ Republic ELECTRUNITE Boiler Tubes
☐ Republic ELECTRUNITE Heat Exchanger Tubes
☐ Carbon ☐ Stainless ☐ FARROWTEST Brochure

Name_____ Title_____

Firm_____

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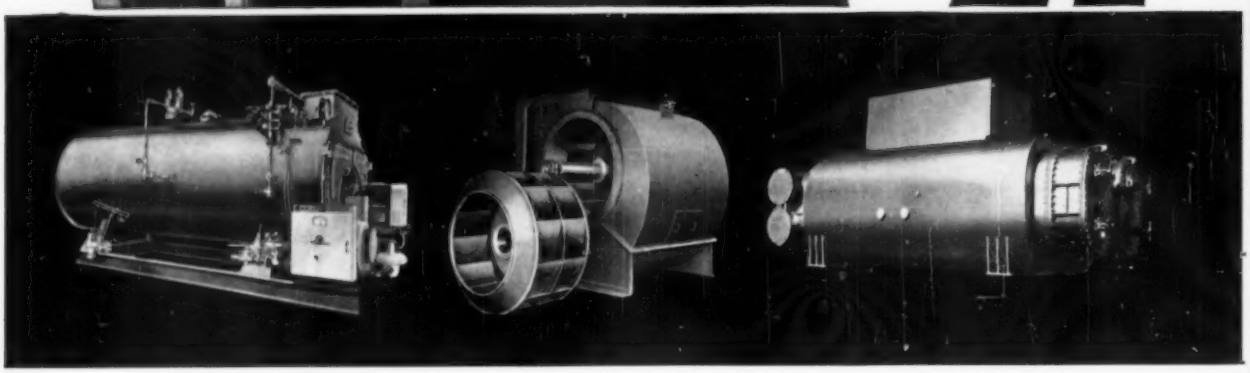
City_____ Zone____ State_____

Evaluating equipment



Firebox, scotch-type, and package boilers for heat, steam, and industrial power.

Mechanical draft fans for induced and forced draft duty in power plants.

Balanced-flow surface condensers for condensing turbo-generator exhaust steam.

One call for all

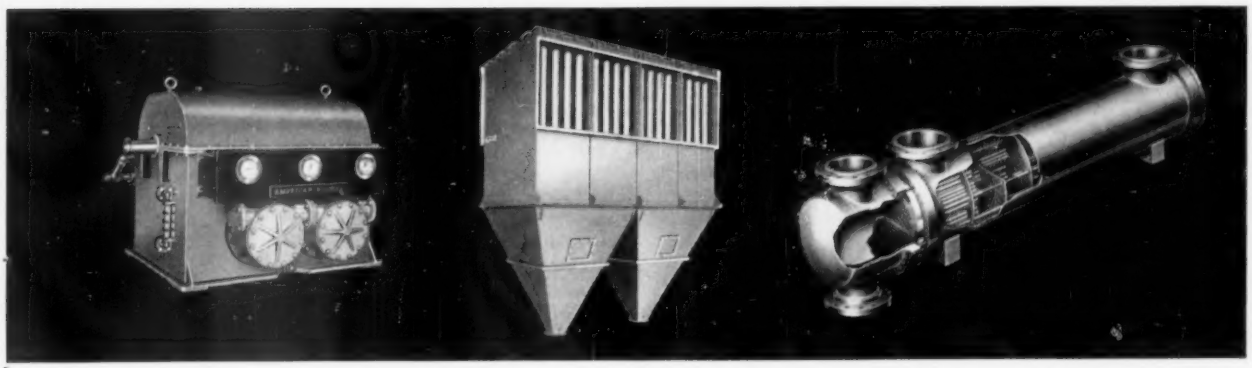
to increase over-all efficiency?

Be sure one of the sources you consider is

AMERICAN-Standard Industrial Division

HERE'S WHY: This one organization encompasses the six major fields of air conditioning, heating, ventilating, heat transfer, dust collection, and fluid drives . . . to offer one-source responsibility for quality and performance in equipment that is designed, engineered, and manufactured to work together.

By combining the engineering backgrounds and product lines of three American-Standard* divisions – American Blower, Ross Heat Exchanger, and Kewanee Boiler – the new Industrial Division brings many benefits to *all* business and industry. There are engineer-staffed offices in all principal cities to work with architects, consulting engineers, and contractors with equipment selection and on-the-job problems. Contact the one nearest you. American-Standard Industrial Division, Detroit 32, Michigan. In Canada: American-Standard Products (Canada) Limited, Toronto, Ontario.



Fluid drives for adjustable-speed control of feed-pump flow and fan volume.

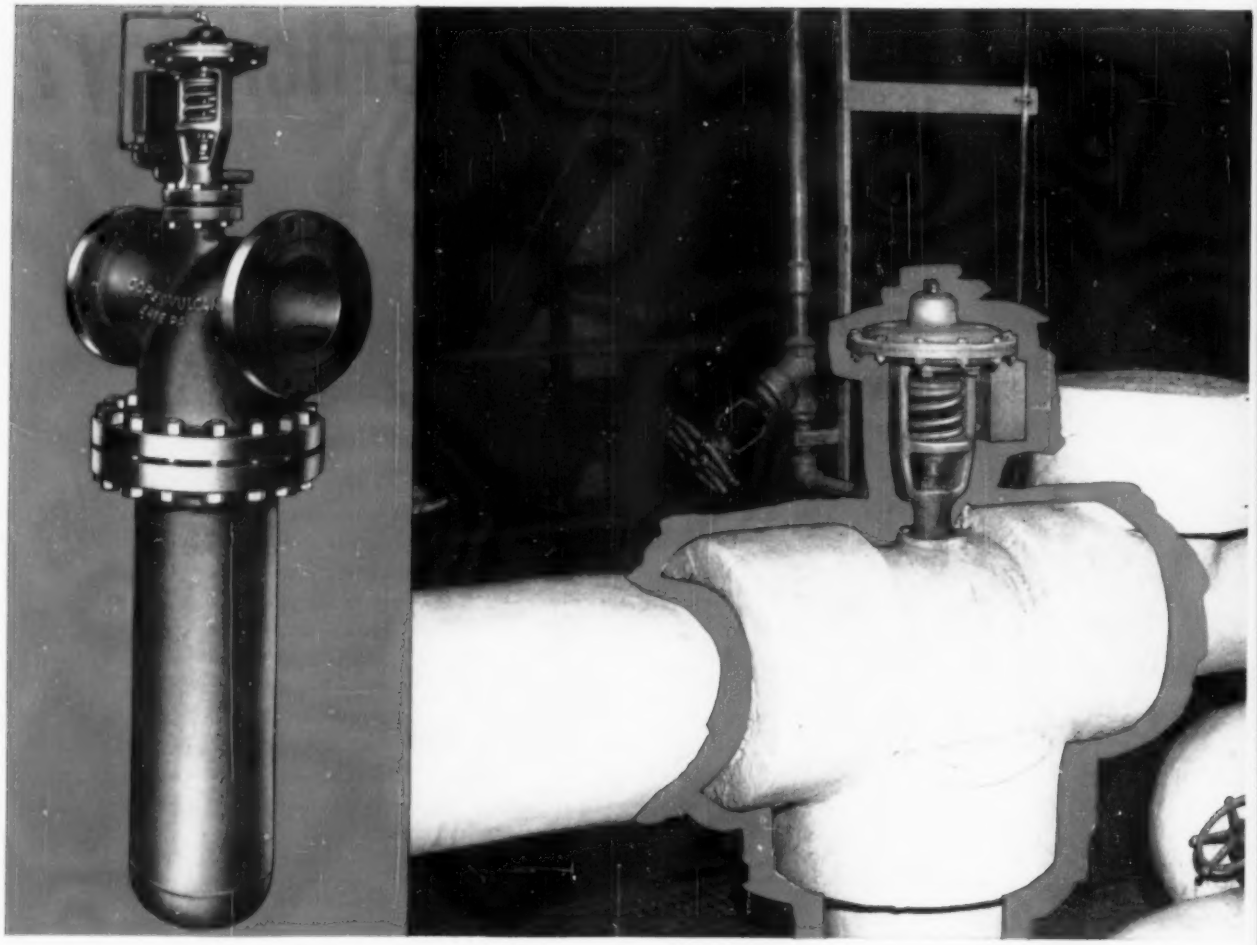
Dust collectors and precipitators for recovering fly ash, eliminating dust.

Standard and engineered heat exchangers and feedwater heaters for every duty.

*AMERICAN-Standard and Standard ⛨ are trademarks of American Radiator & Standard Sanitary Corporation.

AMERICAN-Standard
INDUSTRIAL DIVISION

AMERICAN BLOWER PRODUCTS • ROSS PRODUCTS • KEWANEE PRODUCTS



Copes-Vulcan reducing and desuperheating station takes load swings at Barrett Plant

Long Island Lighting Company uses a Copes-Vulcan desuperheating and pressure reducing station at their Edward F. Barrett Station. Steam is delivered to the reducing and desuperheating station at 2015 psig and 1005 F. Specifications require the station to condition flows of 500 to 25,000 pounds per hour down to 165 psig and 385-400 F. Maximum flow is 1000 pounds per hour in spring and fall, 3,000 pounds in winter.

During the evening hours in the winter, the generating unit comes down to half load or less, requiring the PR&D station to feed pre-heater steam coils. When the steam coils are supplied from the PR&D station the load swings from 3,000 to 17,000 pounds per hour in 30 seconds.

Made up of a Copes-Vulcan Carburetor-Type Desuperheater and a heavy service, piston-type valve, this station has provided trouble-free operation since its installation two years ago.

Besides the Carburetor-Type, Copes-Vulcan offers two other types of desuperheaters.

Steam-Assist Desuperheater has negligible permanent pressure loss on loads of 15% to 100% of maximum. This in-line desuperheater normally uses assisting steam only on light loads where control is most difficult. Write for Bulletin 1024-A.

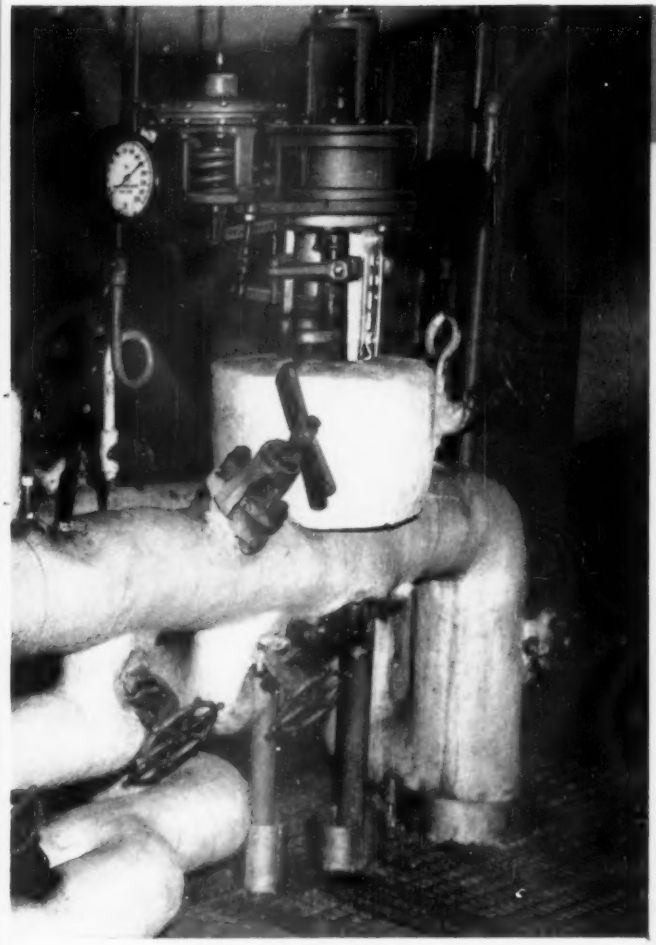
Variable-Orifice Desuperheater holds reduced steam temperatures constant less than 20 feet downstream from desuperheater outlet over a 50-to-1 load range. Write for Bulletin 1037.

COPES VULCAN

Copes-Vulcan Division
BLAW-KNOX COMPANY
Erie 4, Pennsylvania

BLAW-KNOX

C-V NEWS NOTES



Above—**3,000 TO 17,000 POUNDS PER HOUR IN 30 SECONDS . . .** That's the load swing handled by the Copes-Vulcan pressure reducing and desuperheating station during winter nights when steam coils are put into service.

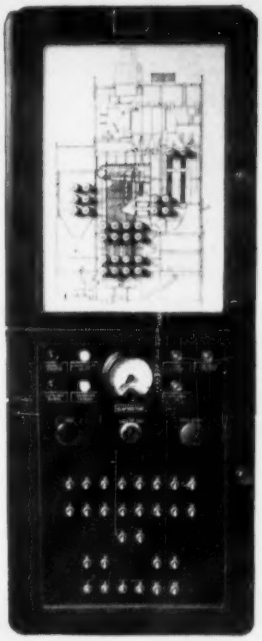
Upper left—**CARBURETOR-TYPE DESUPERHEATER USED AT BARRETT STATION.** Superheated steam is directed to pass the spray nozzle, which injects cooling water into the steam before it enters the mixing chamber. The flow of cooling-water is controlled at the spray nozzle to maintain a pressure drop across the nozzle at all flows. Cooling-water spray entering the mixing chamber is instantly evaporated, thus lowering the steam temperature to that desired. Final temperature may be held within plus-or-minus 5°F.

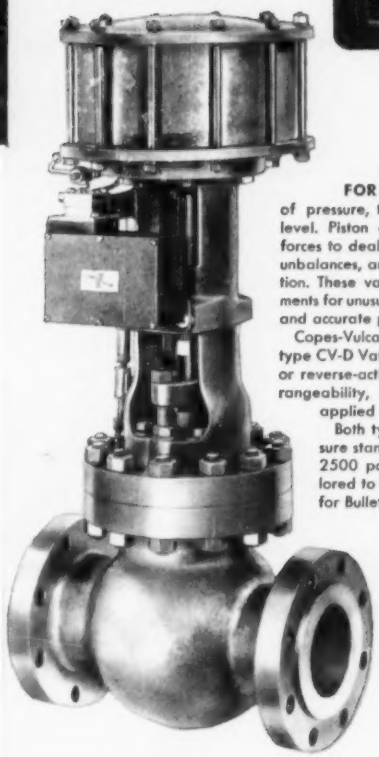
Available in standard 2" through 12" sizes, in 150- through 600-pound pressure standards for cast steel. Larger sizes and higher pressure standards are available on special application. Write for Bulletin 1056.

BARRETT STATION CONTROLS SOOT BLOWING on Unit 1 with a Vulcan Automatic-Sequential System. Vulcan Automatic-Sequential Control Systems can use steam, air, or a combination of both as the blowing medium.

Without leaving the panel, the operator can pre-select any number of units to be operated through automatic sequence, or individually . . . may reverse any soot blower at any point in its operating cycle . . . or switch from automatic-sequential to single-unit operation.

For details on Vulcan's complete line of automatic soot blowing stations, write for Bulletin 1029. (Panel shown gives automatic-sequential control for up to 60 soot blowers.)





PISTON-TYPE VALVES FOR PRECISION CONTROL of pressure, temperature, and liquid level. Piston actuation develops high forces to deal with static and dynamic unbalances, and with stuffing box friction. These valves meet rigid requirements for unusually high operating force and accurate positioning.

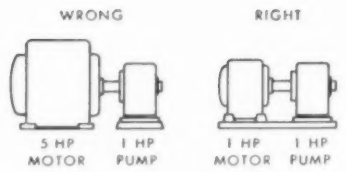
Copes-Vulcan also builds diaphragm-type CV-D Valves which may be direct- or reverse-acting. They offer excellent rangeability, and can be profitably applied to many jobs.

Both types available for pressure standards from 125 through 2500 pounds. Each valve is tailored to its job. For details, write for Bulletin 1027.

Tips on evaluating Electrical

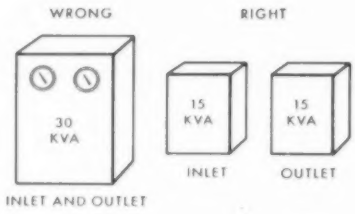
Matched Electrical Sets

You wouldn't use a 5 h.p. motor to run a pump that required only one h.p. Similarly, electrical sets should be *matched* to the requirements of the specific job. Electrical sets should be sized according to gas conditions, dust conditions, and other operating characteristics, and in accord with manufacturers' past experience on similar installations. *Don't be misled by high KVA ratings on the electrical sets.* The precipitator will only absorb a certain amount of power and the sets should be sized accordingly. A large excess of installed power, which will never be used, means inefficient use of the equipment.



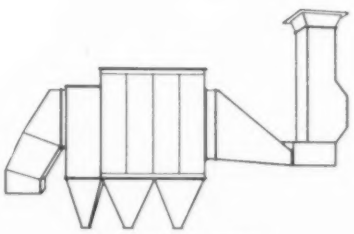
Varied Electrical Conditions

Electrical conditions in a precipitator can vary widely at different parts of the precipitator. For instance, a high voltage, low current condition usually prevails at the inlet where the dust load is high, as compared to a lower voltage higher current condition at the outlet. Consequently, it is good design (and a necessity for high efficiency) to furnish several electrical sections in series, with energization from separate electrical sets so that each section can be adjusted to best suit the conditions.



Gas Distribution

Remember that gas distribution, gas baffling, and provision against hopper sweeping all have a large influence on collection efficiency. The gas flow system should be analyzed as closely as possible, both in the precipitator and in the associated ductwork. If in doubt, have a three-dimensional gas flow study made. Two-dimensional gas flow studies *are not as accurate* and may lead to erroneous conclusions.



RESEARCH

RESEARCH-COTTRELL, INC. Main Office and Plant: Bound Brook, New Jersey

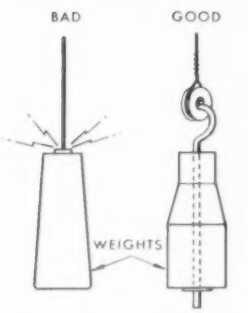
GC 191

Precipitators

Some helpful hints to aid in selecting a properly designed unit

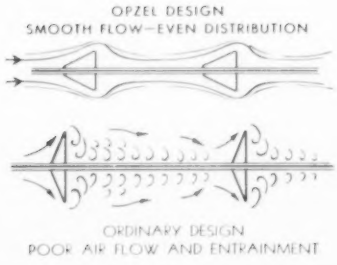
Rapping Intensity

Rappers should have easy means to vary the intensity of the blow to suit variations in operating conditions. A pre-set intensity setting cannot possibly give proper rapping over the normal range of operation. If too soft, build-up will occur which will disturb electrical conditions. If too hard, there will be reentrainment. Means of intensity adjustment are necessary to avoid drop-off of precipitator efficiency as conditions change.



Corona Discharge

It is a relatively easy matter to obtain a corona discharge in an electrostatic precipitator. Many types of discharge electrodes have been used over the past forty years, including ribbons, squares, twisted squares, star shaped sections, coiled wires, wires with prongs and projections, most of which give entirely adequate corona conditions. Final choice then gets down to mechanical factors such as strength of wire, method of support to avoid stress points, and ease of handling. There are many claims made for various types of wires but after investigating and testing hundreds of different kinds, we find a straight round wire about .1" diameter to be best.

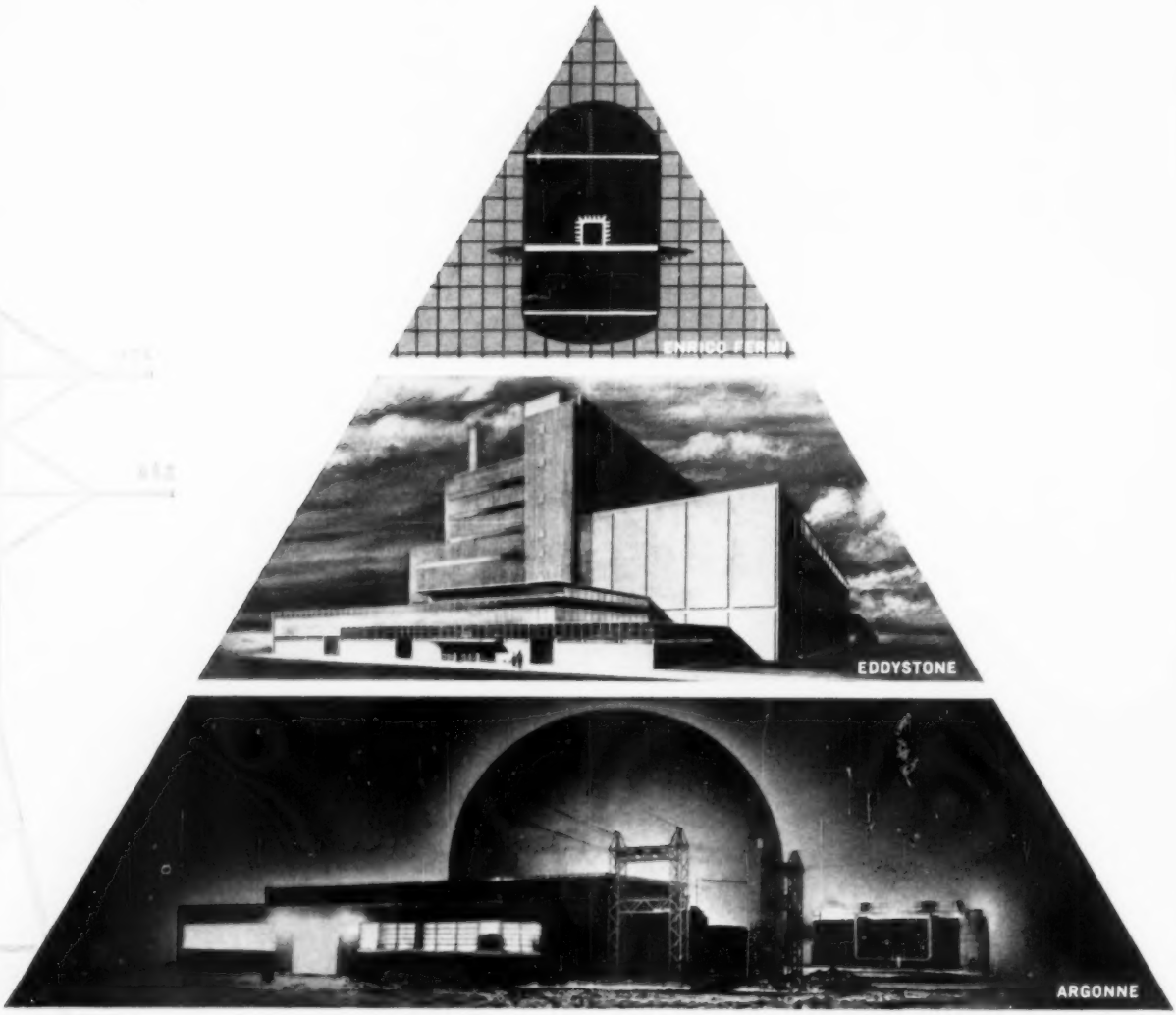


Baffle Design

Careful attention to the design of baffles on the collecting plates is most important. Small amounts of reentrainment mean tremendous differences in over-all collection efficiencies. It is seen that the "quality" of the collecting surface is far more important than quantity — quantity (sq. ft. of surface or treatment time) in itself is not a criterion of performance.

-COTTRELL

Representatives in all major cities of U.S. and Canada



GRAVER

CONTRIBUTES TO POWER PROGRESS *with advanced water treatment methods and processes*

Enrico Fermi Atomic Power Plant. First large-scale fast-breeder reactor in the United States. Built to produce steam for commercial electric power and to advance research. To go into operation in 1960.

Eddystone Station, Philadelphia Electric Company. Largest supercritical plant in the world—highest temperature (1200°F), highest pressure (5000 psig). To go into operation in 1959.

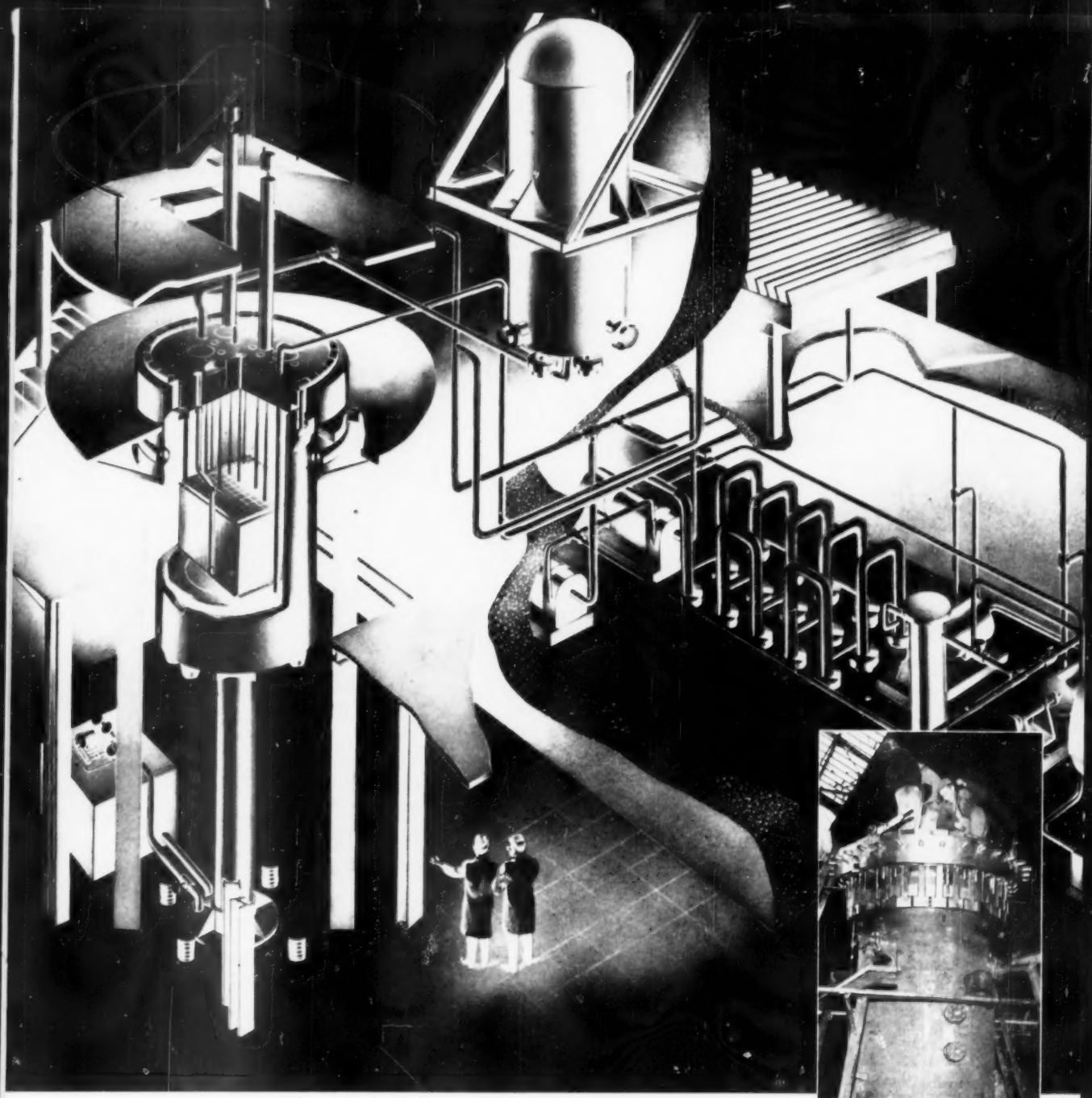
Argonne National Laboratory, the Experimental Boiling Water Reactor. First reactor built to explore the commercial use of atomic energy. Now in operation.

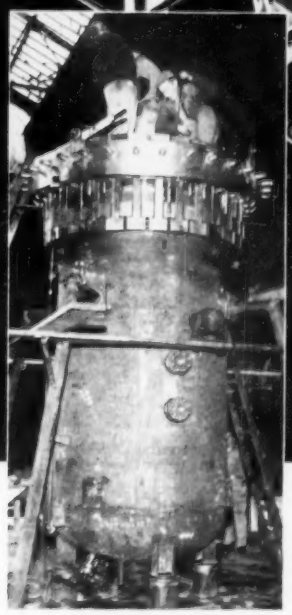
All three installations have in common not only unique water treatment requirements but also the incorporation of scavenger demineralizers. These units were pioneered by Graver Water Conditioning Co. to meet the ultra-pure water requirements of supercritical and nuclear power plants. Now Graver is offering them for use in sub-critical plants where they represent a major breakthrough in problems of internal contamination which are of concern to all power plants.

Our work in boiler feedwater treatment for sub-critical, supercritical and nuclear power plants shows the breadth of Graver's contribution to power progress. Our pioneering of scavenger demineralizers for wide application is but one example of the research and development which goes on constantly at Graver to keep apace of this fast growing industry and to introduce new equipment and methods for the further advancement of the field.

GRAVER

Industrial Water Treatment Dept. I-322
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.





The Proof Test Reactor Pressure Vessel, with quick-opening closure, in Kellogg's Jersey City plant just prior to shipment.

FIRST EVER BUILT

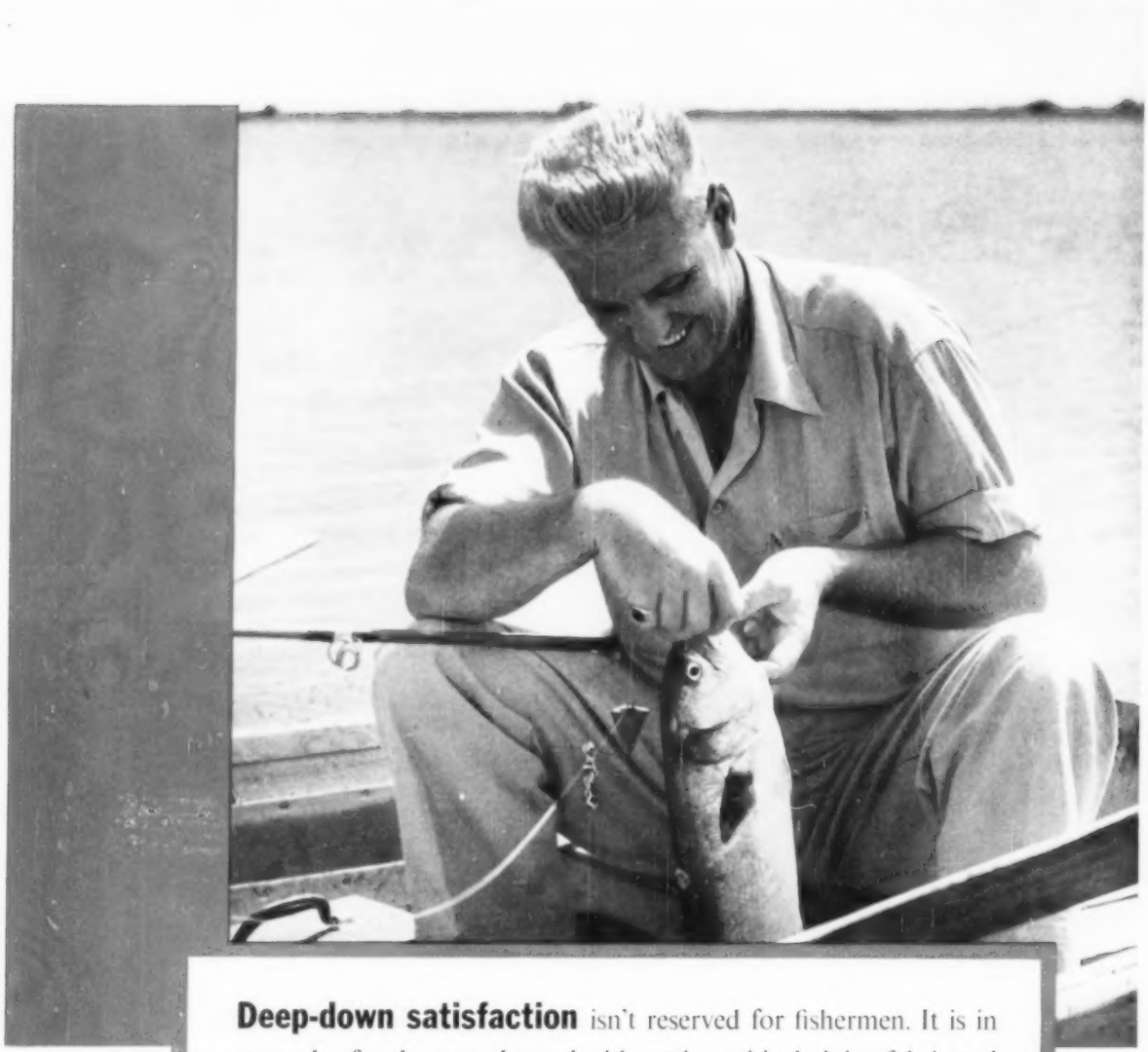
—this high-temperature nuclear test reactor was developed by Knolls Atomic Power Laboratory to confirm design data for reactor cores of the submarine Triton. Vital core components and instrumentation are housed in a 32½-ton stainless steel pressure vessel. Required to withstand 550 F., 1,500 psi, this vessel and its novel, quick-opening closure were designed and fabricated for KAPL by The M. W. Kellogg Company.

Additional examples of Kellogg's ability to design and fabricate nuclear equipment to the most exacting standards include the primary coolant stainless piping for two other nuclear plants. Kellogg is also designing and fabricating heat exchangers for still another nuclear plant. Kellogg's Fabricated Products Sales Division welcomes inquiries for the design and fabrication of nuclear equipment.

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corp., London • Kellogg Pan American Corp., Buenos Aires • Société Kellogg, Paris • Companhia Kellogg Brasileira, Rio de Janeiro • Compañía Kellogg de Venezuela, Caracas



Deep-down satisfaction isn't reserved for fishermen. It is in store also for the men charged with getting critical piping fabricated and erected in their power or processing plants . . . provided they delegate such work directly to experienced specialists. Ask us in.

W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

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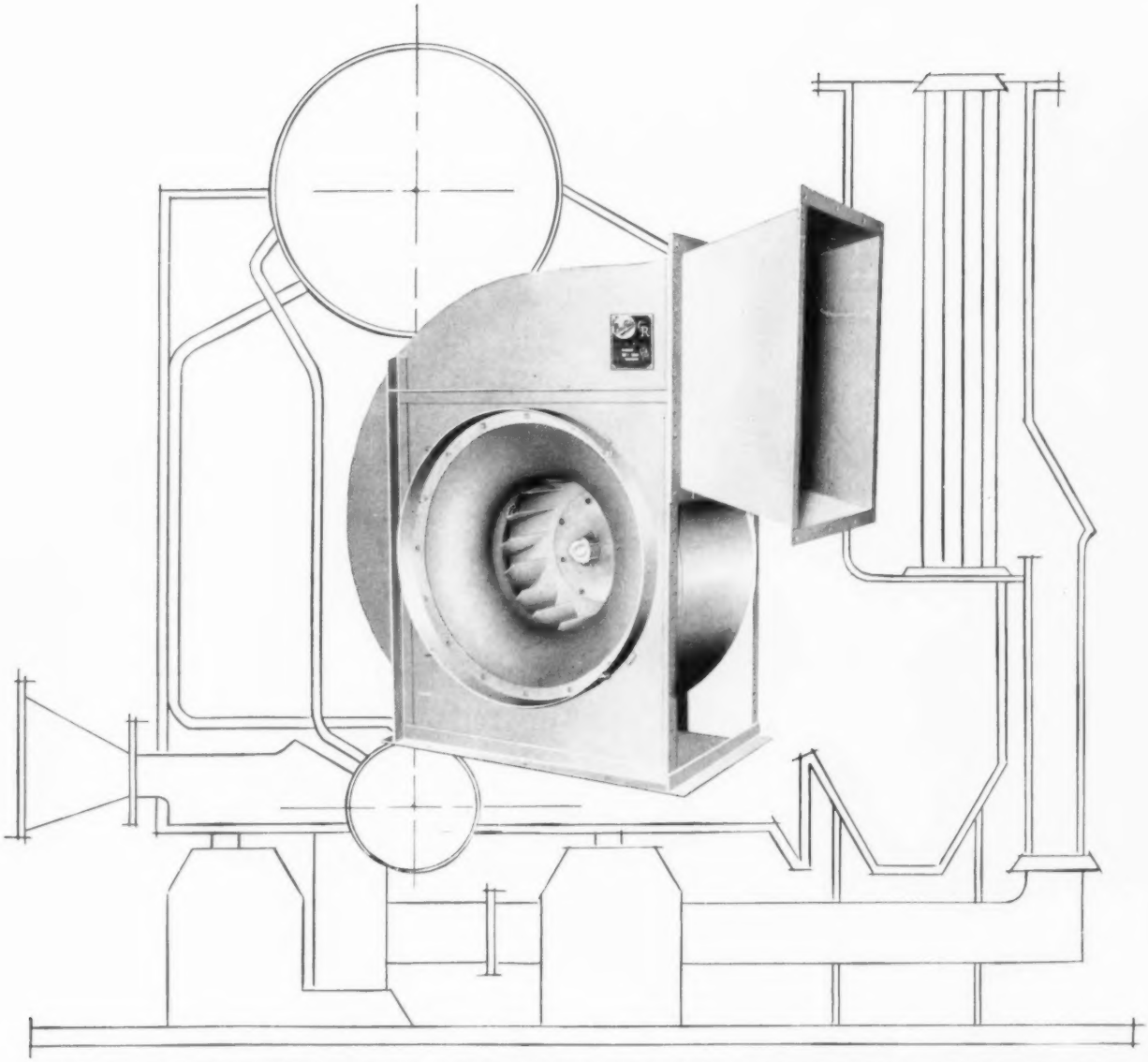

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"BUFFALO" TYPE "CR" RADIAL WHEEL DRAFT FANS

Combining sharply rising pressure and horsepower characteristics with high static efficiency and resistance to abrasive effects, the "CR" is an ideal fan for stoker-fired or pulverized coal boilers. It is also proving an excellent choice for handling air with dust loadings in a wide range of industrial jobs. Too, these same high-pressure, high-capacity characteristics may mean a smaller fan for many direct-connected applications — a saving in first cost.

Write for Bulletin FD 205 and see the dependable, stable performance built into this husky radial wheel fan for constant volume or inlet-dampered operation. It's one of a *series* of specialized "Buffalo" Draft Fans — including airfoil and backward curve designs with a wide choice of wheels — to give you the best service your operation requires.

NOTE: *Every "Buffalo" Fan has the exclusive "Q" Factor—the built-in Quality which provides trouble-free satisfaction and long life.*

BUFFALO FORGE COMPANY

BUFFALO, N. Y.

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo"

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

For Fly Ash Collection, here are

3,370 REASONS WHY

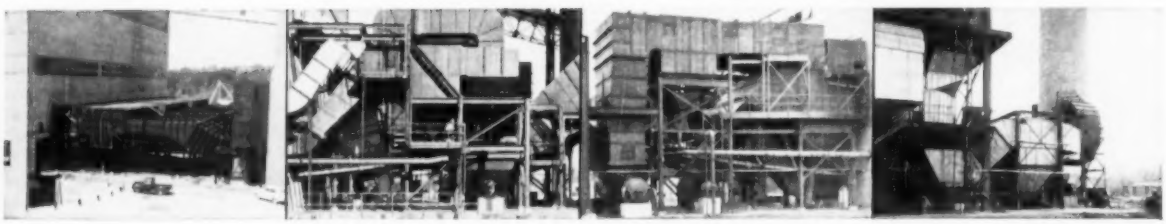
You're Years Ahead with MULTICLONE

The tabulation sheet shown here is over 40 feet long, filled top to bottom with single-spaced typewriter listings as shown in the enlarged section above . . .

- Each typewritten line tabulates an installation of Multiclone equipment—an installation of from one to nine separate Multiclone units!
- These installations have been made in all parts of the world, in plants operating under widely-varying load, atmospheric and fuel conditions!
- They include installations on virtually every type of steam power plant (i.e. pulverized coal fuel boilers, spreader stoker boilers, chain grate boilers, underfeed stoker boilers, etc.)

New Multiclone installations are being made every day, but at the time this tabulation was made there were 3,370 Multiclone units giving superior service to industry throughout the United States, Canada and other countries.

What does this mean to you? Simply this—when you select "Multiclone" you are getting equipment that has over a quarter-century of experience behind it . . . equipment backed by the industry's greatest fund of "know-how" in modern small tube, high-efficiency cyclonic collection. Although this unequalled experience is a part of every Multiclone installation, you pay nothing extra for this vital advantage!



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CMP Combination Units
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Engineers and Constructors of Equipment for Collection of Suspended Material from Gases . . . and Equipment for the Process Industries

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Representatives in all principal cities

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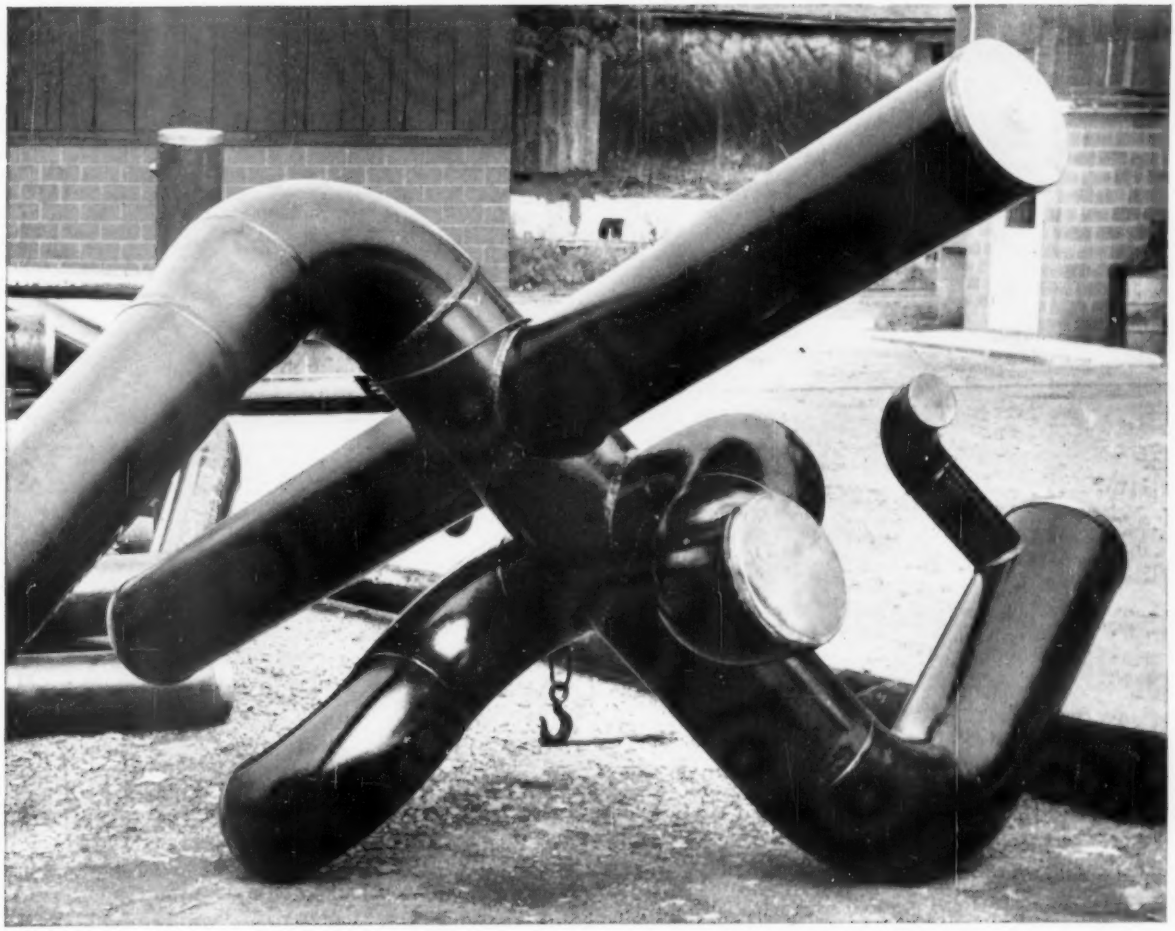

Shop fabrication of complex shapes such as this ⅜" wall service water header simplifies field erection.

Minimum field welding and fitting means faster installation and **lower overall cost of installed piping**

The service water header shown is part of an order which included all piping six inches and larger for a 325MW central station. The boiler will operate at 2000 psi and 1050–1000F. Main steam header was fabricated from 2¼ chrome, 1 moly pipe, 19" O.D. x 3½" wall.

Careful engineering, pre-planning and fabrication to high standards are the basic reasons why this job was erected with field welding and on-the-spot fitting held to a time-saving minimum. Contractor and owner both benefited from the ease with which the piping went into place—both saved money on the overall cost.

Complete facilities, engineering service, accurate fabrication that is quality control checked at every stage, plus erection service if desired . . . these are available to you on your next job. Take advantage of the *complete* piping services offered by Dravo. For full information, write DRAVO CORPORATION, PITTSBURGH 22, PENNSYLVANIA.

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Blast furnace blowers • boiler and power plants • bridge sub-structures • cab conditioners • docks and unloaders • dredging • fabricated piping foundations • gantry and floating cranes • gas and oil pumping stations • locks and dams • ore and coal bridges • process equipment • pumphouses and intakes • river sand and gravel • sintering plants • slopes, shafts, tunnels • space heaters • steel grating • towboats, barges, river transportation

What's the latest in

C-E BOILERS* FOR HIGHEST STEAM PRESSURES

COMPANY	STATION	No. of Units	Throttle Pressure	Steam Temperature	Capacity—kw Total
		FOR SUPERCRITICAL PRESSURES			
Philadelphia Electric Co.	Eddystone	1	5000	1200/1050/1050	325,000
Philadelphia Electric Co.	Eddystone	1	3500	1050/1050/1050	325,000
Cleveland Electric Illuminating Co.	Avon	1	3500	1100/1050	215,000
		FOR SUBCRITICAL PRESSURES — ABOVE 2400-LB			
Metropolitan Edison Co.	Portland	1	2520	1050/1050	165,000
Metropolitan Edison Co.	Portland	1	2520	1050/1000	225,000
New England Power Co.	Brayton	1	2520	1000/1000	250,000
Virginia Electric & Power Co.	Chesterfield	1	2520	1000/1000	167,000
Virginia Electric & Power Co.	Possum Point	1	2520	1000/1000	225,000
Dayton Power & Light Co.	Tait	2	2490	1050/1000	260,000
		FOR SUBCRITICAL PRESSURE — 2400-LB			
Central Hudson Gas & Electric Co.	Danskammer	1	2400	1050/1000	125,000
Cincinnati Gas & Electric Co.	Beckjord	1	2400	1050/1000	156,250
Cincinnati Gas & Electric Co.	Miami Fort	1	2400	1050/1000	156,250
Cleveland Electric Illuminating Co.	Ashtabula	1	2400	1050/1050	225,000
Cleveland Electric Illuminating Co.	Eastlake	1	2400	1050/1050	187,500
Consumers Power Co.	Karn	1	2400	1050/1050	250,000
Consumers Power Co.	Port Sheldon	1	2400	1050/1000	250,000
Detroit Edison Co.	St. Clair	1	2400	1050/1000	325,000
Duke Power Co.	Allen	2	2400	1050/1000	330,000
Duke Power Co.	Allen	3	2400	1050/1000	825,000
Duke Power Co.	Lee	1	2400	1050/1000	165,000
Niagara Mohawk Power Co.	Dunkirk	2	2400	1050/1000	400,000
Niagara Mohawk Power Co.	Huntley	2	2400	1050/1000	400,000
Pennsylvania Electric Co.	Shawville	2	2400	1050/1000	330,000
Pennsylvania Power & Light Co.	Brunner Island	1	2400	1000/1000	300,000
Philadelphia Electric Co.	Schuylkill	1	2400	1050/1000	175,000
Potomac Electric Co.	Dickerson	2	2400	1050/1000	350,000
South Carolina Electric & Gas Co.	McMeekin	3	2400	1050/1000	375,000
Tennessee Valley Authority	Widows Creek	1	2400	1050/1000	500,000

* The above list covers American utilities only. Abroad, too, the C-E Controlled Circulation Boiler has achieved a predominant position for 2400-lb applications, evidenced by orders placed with C-E or its licensees for 23 units with an aggregate capacity of 5,030,750 kw.

COMBUSTION

Combustion Engineering Building

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS

Steam Pressures?

Although one unit for supercritical pressure is presently in service and others are under construction, today's pressure plateau is in the 2400-2520 psi range.

It appears inevitable that many new units will be purchased for this pressure cycle, since it offers a heat rate gain of about 185 Btu over the 1800-psi pressure group. With ever-increasing fuel prices, there is ample incentive to move into this pressure range.

In the entire area of high pressures, temperatures and capacities, Combustion is playing a leading role. As indicated by the list on the opposite page, 38 C-E units have been purchased for use in the 2400-lb pressure range and above – 32 of the Controlled Circulation design. The turbine-generator capacity for the 38 units listed totals about 8-million kilowatts. Already, 14 of these units are in service supplying steam to produce more than 2-million kw. One has been in service over 3 years.

Later this year, a C-E Sulzer Monotube unit, designed for the highest steam pressure and temperature ever employed (5000 psi at 1200 F), will go into service at Eddystone Station of Philadelphia Electric Company. Two more supercritical pressure units, for 3500 psi, are presently under construction. Other similar units for subcritical pressures are already in service for Metropolitan Edison Company and Dayton Power & Light Co.

Along with higher pressure, the trend is toward higher unit capacities. In another year, the average size of high pressure units purchased should be up to 250 megawatts as compared to an average of 200 mw, for the units listed on the opposite page.

ENGINEERING

200 Madison Avenue, New York 16, N. Y.

C-218

Check this O_2 analyzer in 1 minute!

In just 1 minute, an operator can check calibration of this L&N Magnetic O_2 Analyzer . . . can keep an easy watch on overall instrument accuracy, if desired. Under normal use, this check need only be made weekly. A complete calibration, requiring approximately ½-hour, only needs to be made every 3 months. Total calibration time: less than 3 hours a year.

The analyzer's regulating unit (shown above) is located right on the instrument. Calibration is simple since the measuring system is not disturbed. Instrument air serves as the calibrating gas.

Components of the complete L&N O_2 Sampling and Analyzing System include:

1. *Reverse Jet Probe and Steam Sampler*
2. *Sample Averaging Panel (for multi-probe installations)*
3. *Magnetic O_2 Analyzer*
4. *Speedomax® Electronic Recorder*

For further information, contact your nearby L&N Field Engineer or write for our O_2 Analyzing Systems Folder to 4972 Stenton Ave., Philadelphia 44, Pa.

L&N O_2 Analyzing Systems engineered to power-plant standards **LEEDS & NORTHRUP** Instruments Automatic Controls • Furnaces

In an average year, Beacon Coal shipments are transported by over half the Class I railroads in the nation . . . reach customers in over half the states . . . are transshipped via Great Lakes, coastwise, and export. You can always be sure that *your* shipments will be moved and delivered promptly.

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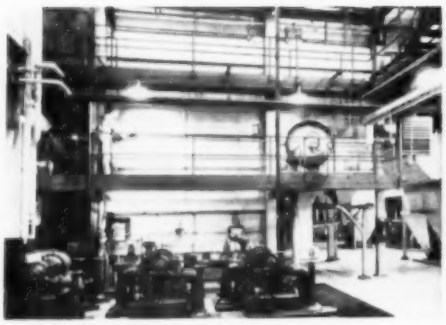
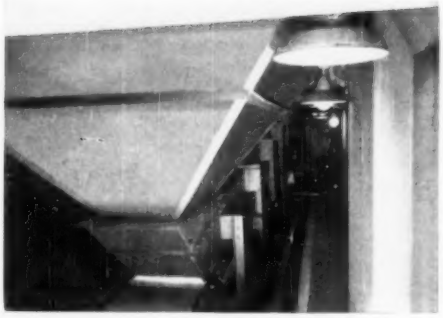
For New England: New England Coal & Coke Co.; For Export: Castner, Curran & Bullitt, Inc.

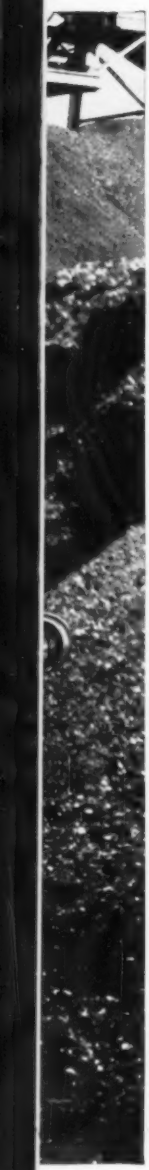


Steam generating plant at Morton, Ill. plant uses two 60,000 lb/hr Wickes boilers, 3 stories high. These are equipped with Hoffman continuous ash-discharge spreader stokers.



Track unloading hopper at York plant. Coal feeds from belt conveyor to bucket conveyor to distributing flight conveyor over storage bunker. Coal handling system by Beaumont Birch.

Ash hopper in Decatur plant. Pneumatic ash removal system by Beaumont Birch Co. connects to vitrified tile ash bin and rotary dustless unloader.



Caterpillar makes tracks for coal

Seven Caterpillar Tractor Co. plants burn coal for low-cost steam generation

When seven plants of a company all burn coal —over 250,000 tons a year—you can be sure there's a *good* reason. At Caterpillar Tractor Co., where steam is used for both process work and heating, coal is burned for low-cost, efficient steam production.

Because of its importance at Caterpillar, steam generation must meet the same standards of efficiency and dependability set up for all phases of plant production. As Caterpillar has expanded from one plant to many, therefore, *each* plant has burned coal.

Coal is lowest cost fuel

Today, *when the annual cost of fuel often equals the original cost of the boilers,* you should know that bituminous coal is the lowest cost fuel in most industrial areas. And modern coal-burning equipment gives you 15% to 50% *more* steam per dollar, while automatic operation trims labor costs and eliminates smoke problems. What's more, tremendous coal reserves and mechanized mining procedures assure you a constantly plentiful supply of coal at stable prices.

Technical advisory service

To help you with fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to address below or send coupon. Ask also for case histories booklet, complete with data sheets. You'll find them informative.

Consult an engineering firm

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you with the efficiency and economy of coal.

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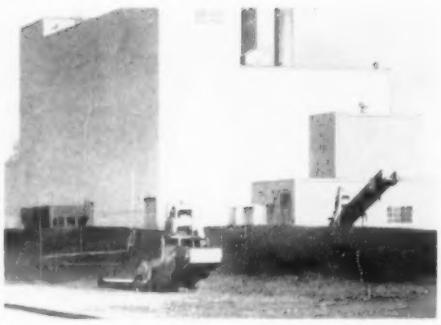
See our listing in *Sweet's*



Exterior view of steam plant at Joliet, Ill. Foreground shows part of outside coal storage area featuring portable car unloader and stacker. Coal is stocked out and reclaimed by Caterpillar bulldozer-equipped crawler tractor.

SEND COUPON FOR NEW BCI PUBLICATIONS. Guide Specifications, with complete equipment criteria and boiler room plans:

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☐ GS-1 (low-pressure heating plant, screw-type underfeed stoker); ☐ GS-2 (high-pressure heating and or process plant, ram-type underfeed stoker); ☐ GS-3 (automatic package boiler for heating and process plants). ☐ Case histories on larger plants.

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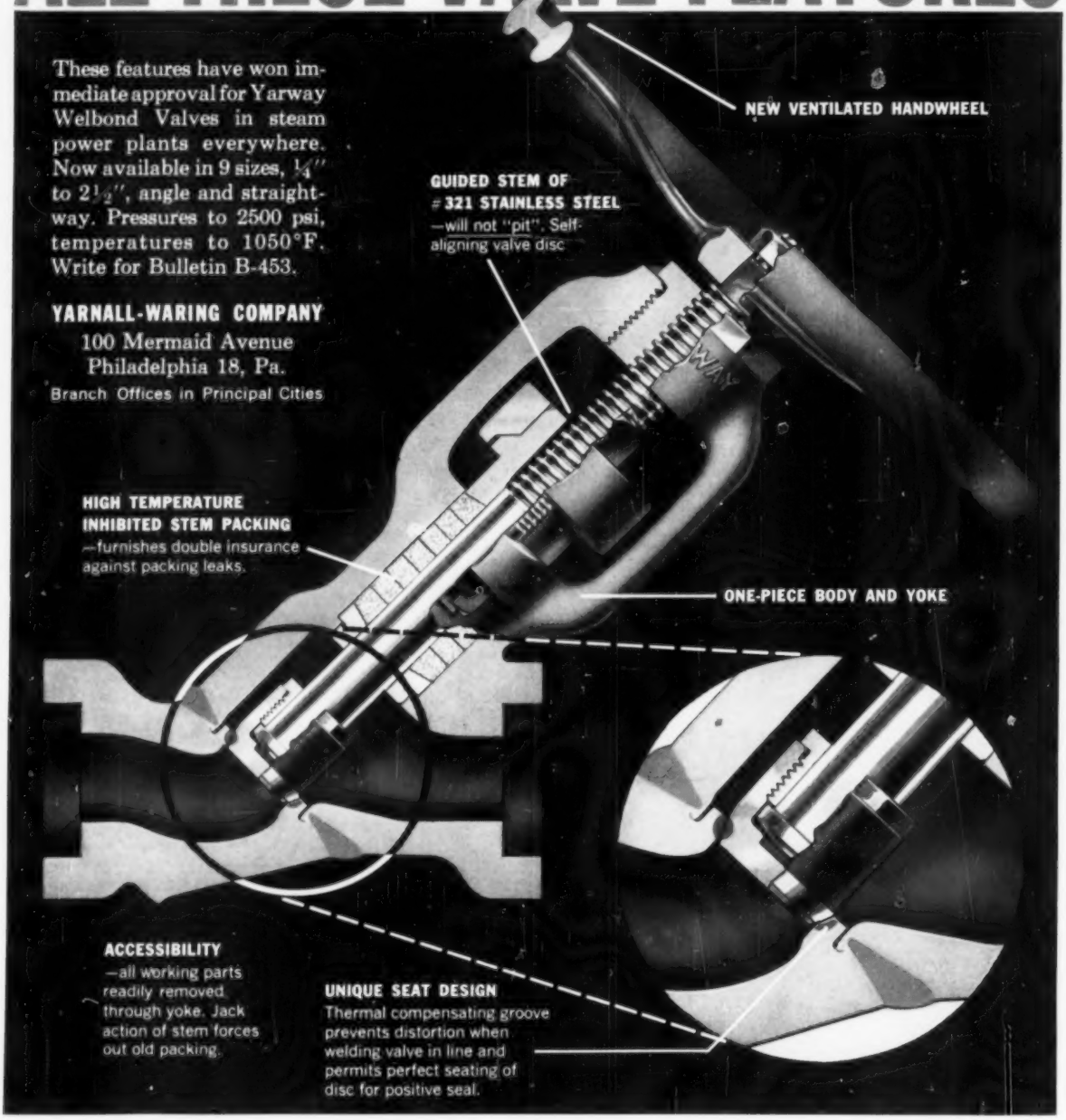
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NEW VENTILATED HANDWHEEL
GUIDED STEM OF #321 STAINLESS STEEL —will not "pit". Self-aligning valve disc
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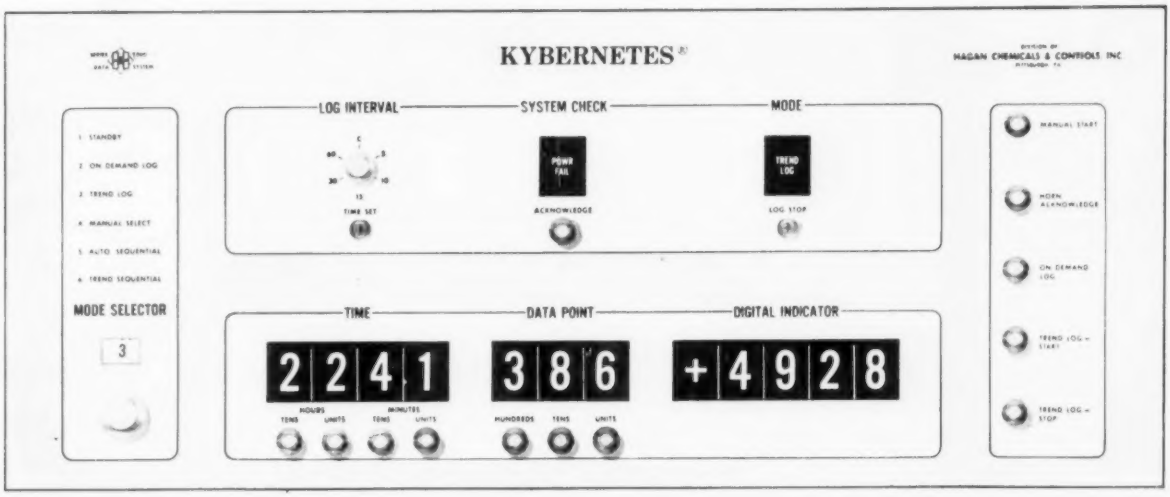
Hagan Chemicals & Controls, Inc., announces the

COMPLETELY NEW



Kybernetes Series 2000 Data Processing System

The new Kybernetes Series 2000 Data Processing System, utilizing solid state components, adds many data handling advances to the outstanding features of the original equipment. Here are some of the features the new Kybernetes system has to offer:

NEW FLEXIBILITY—Basic unit is a simple logging unit for recording process data on a log sheet or other output device. This basic system can be expanded easily, both in terms of the number of points scanned, and the complexity of the operations performed by the unit. For example these can be added as need develops: *Scanning for off-normal conditions—Printed or visual trend of selected variables—Computing and integrating—Automatic programming and optimum setting of control.*

NOTE—*Any* or *all* of these functions may be performed without interrupting any of the other functions. Off-normal scanning *always* proceeds uninterrupted.

OPTIMUM RELIABILITY—Fewer components, simplified design logic and solid state components add to the inherent reliability of the system. All parts have been selected for long life and easy maintenance.

MODULAR CONSTRUCTION simplifies extension of system. Each new function can be added by simply plugging-in appropriate module.

SELF-CHECKING CIRCUITS immediately signal malfunction in any area and spot the area with a warning light.

ACCURACY of 0.1% on all inputs, including non-linear types is achieved by eliminating marginal techniques and components, using the highest quality components and by the use of simplified design logic.

Flexible, accurate and reliable, the new Kybernetes Series 2000 Data Processing System offers many previously unattainable advantages. Designed for maximum usefulness with minimum investment, *the new Kybernetes system permits the addition of functions as needed, including complete computer control.* A new brochure describes these advantages in detail. Write today for your copy; ask for Bulletin MSP-161.

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DIVISIONS: CALGON COMPANY, HALL LABORATORIES

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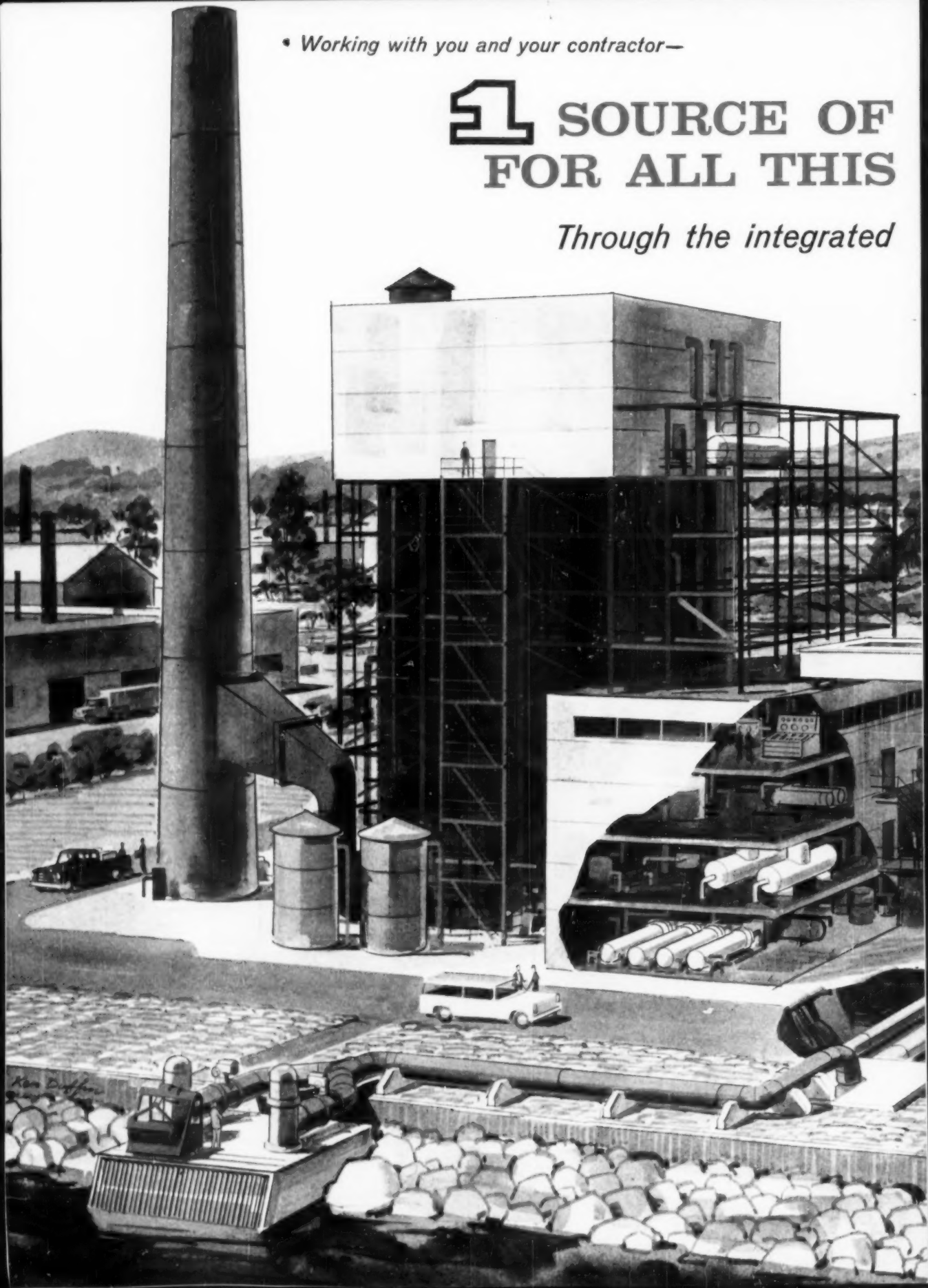

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facilities of YUBA—NATIONWIDE to serve you best

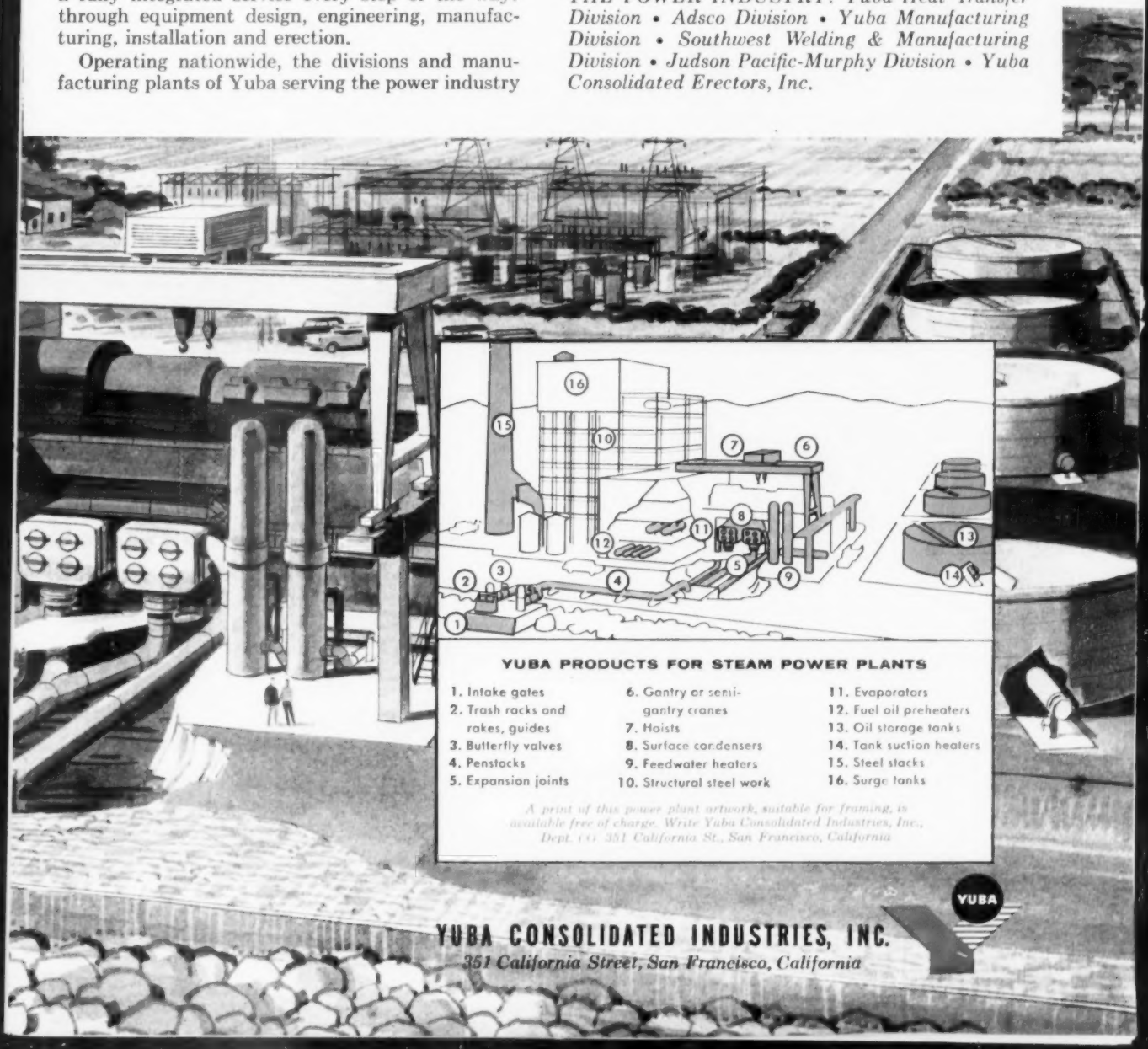
The problem of coordinating all the purchases and delivery of specialized equipment for steam plants can be greatly simplified – when it is packaged as a single responsibility with Yuba.

The advantages to you, your consultants and your contractor are many. They can easily add up to major savings in time, money and trouble. The experienced Yuba organization is geared to deliver a fully integrated service every step of the way: through equipment design, engineering, manufacturing, installation and erection.

Operating nationwide, the divisions and manufacturing plants of Yuba serving the power industry are ideally equipped and located to maintain the highest product quality standards and meet the most demanding completion dates – economically.

Call in your Yuba man. Discuss your plans and problems with him. See how your job can be made easier with his and Yuba's help.

DIVISIONS AND SUBSIDIARIES SERVING THE POWER INDUSTRY: Yuba Heat Transfer Division • Adsco Division • Yuba Manufacturing Division • Southwest Welding & Manufacturing Division • Judson Pacific-Murphy Division • Yuba Consolidated Erectors, Inc.



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6. Gantry or semi-gantry cranes
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11. Evaporators
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16. Surge tanks

A print of this power plant artwork, suitable for framing, is available free of charge. Write Yuba Consolidated Industries, Inc., Dept. 44, 351 California St., San Francisco, California

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DAMPNEY COATINGS LIVE WITH IT!

True measure of a high-heat coating's worth is *continuous operation at rated temperature*. Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000°F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

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steam lines	•	precipitators
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Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

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THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

Coatings for all temperatures to high heat— all corrosive environments.

207

6 Ton Hot Reheat Header

Model test set-up of hot reheat line as reproduced above is approximately 1/10th actual size of the model. Circled area shows position of chrome-moly header in the line.

Size of this hot reheat header can be seen by comparison with men in the picture. It is 21" O.D., fabricated of 2¼% chrome, 1% molybdenum steel.

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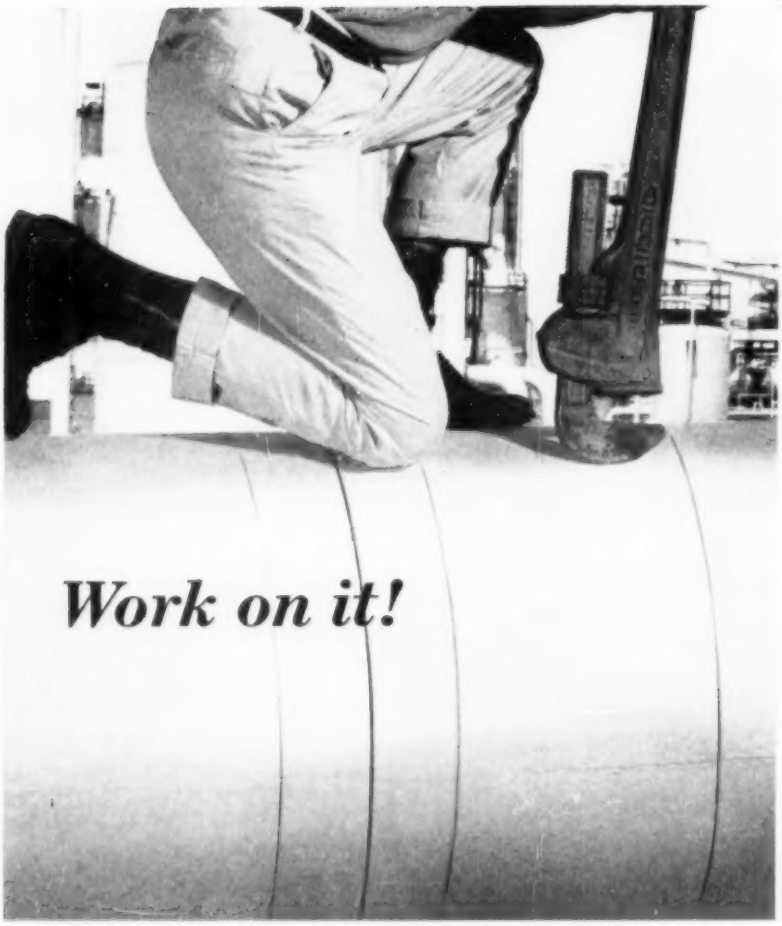

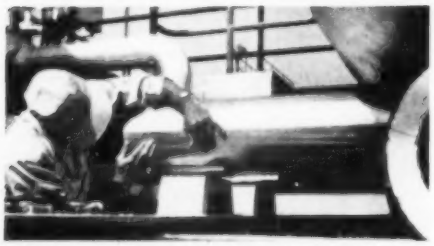

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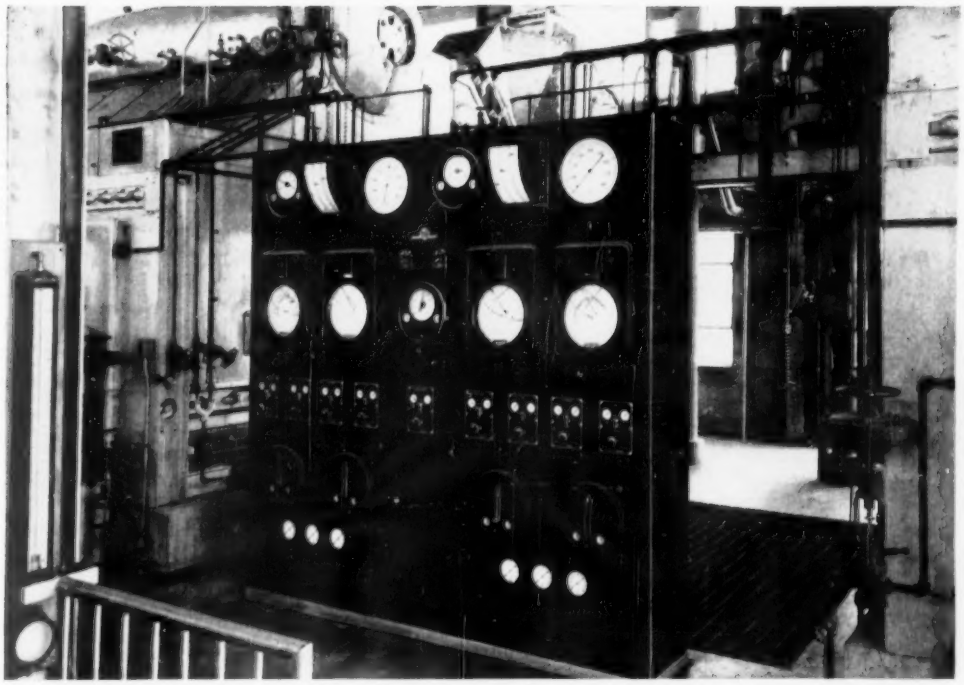

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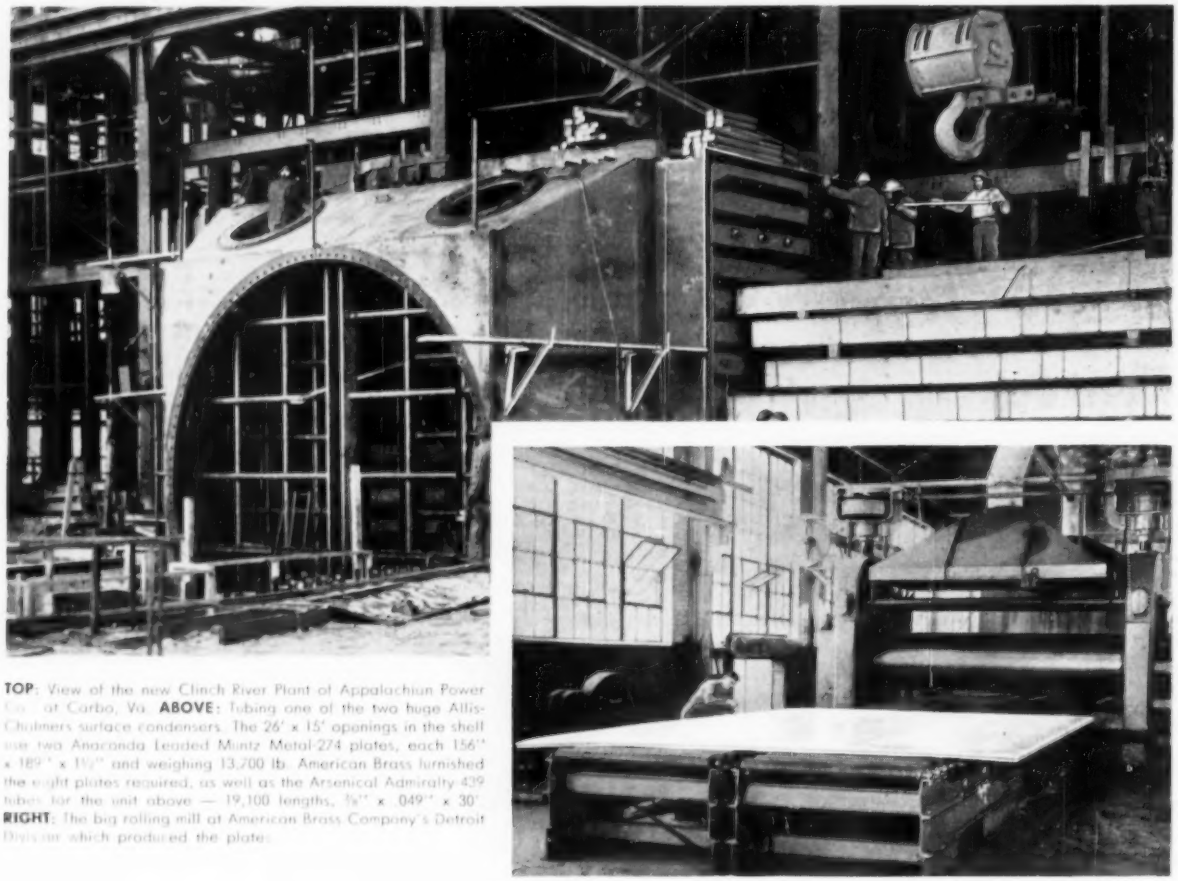

TOP: View of the new Clinch River Plant of Appalachian Power Co. at Carbo, Va. **ABOVE:** Tubing one of the two huge Allis-Chalmers surface condensers. The 26' x 15' openings in the shell use two Anaconda Leaded Muntz Metal 274 plates, each 156" x 189" x 1½" and weighing 13,700 lb. American Brass furnished the eight plates required, as well as the Arsenical Admiralty 439 tubes for the unit above — 19,100 lengths, ⅝" x .049" x 30'. **RIGHT:** The big rolling mill at American Brass Company's Detroit Division which produced the plates.

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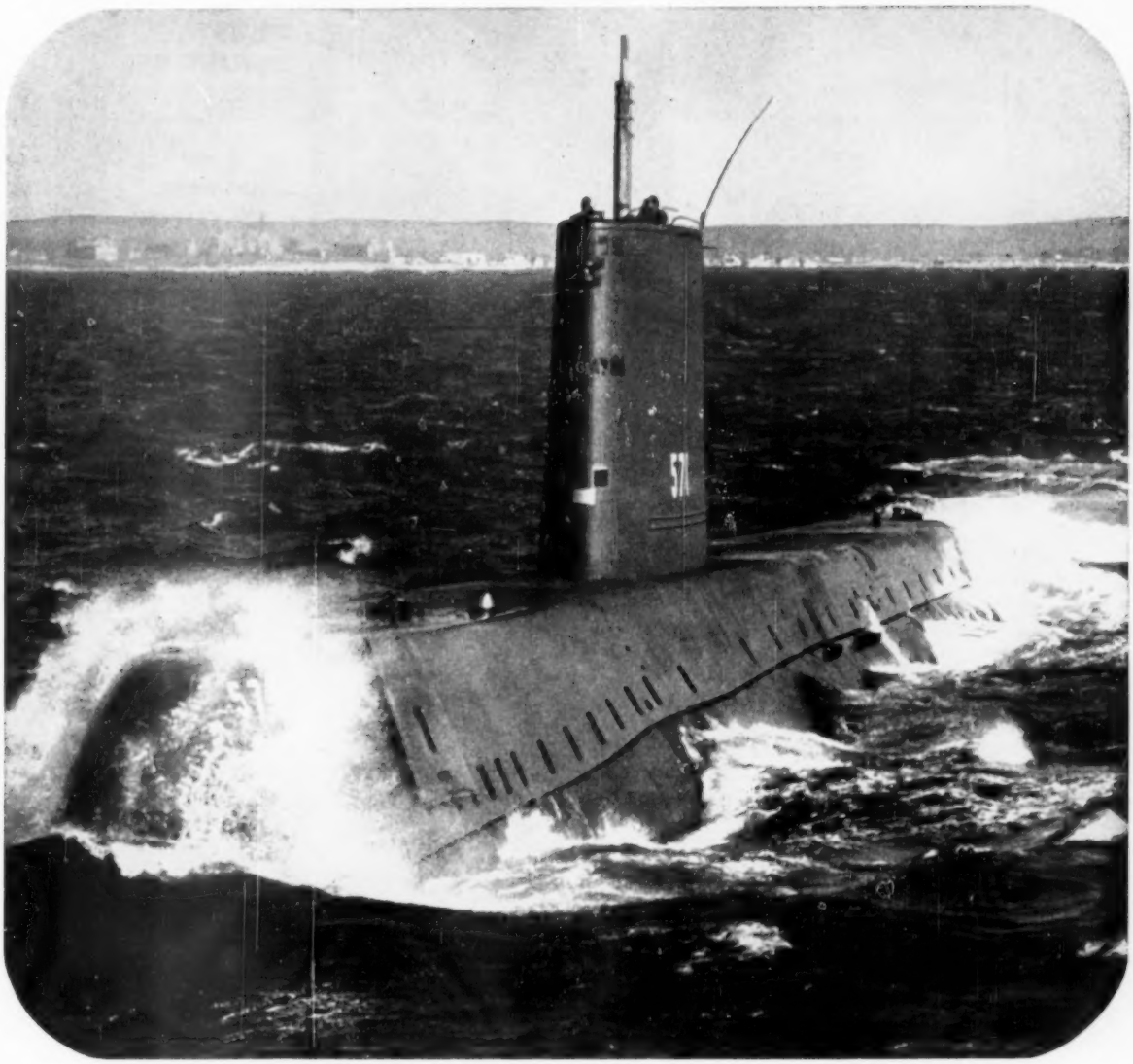

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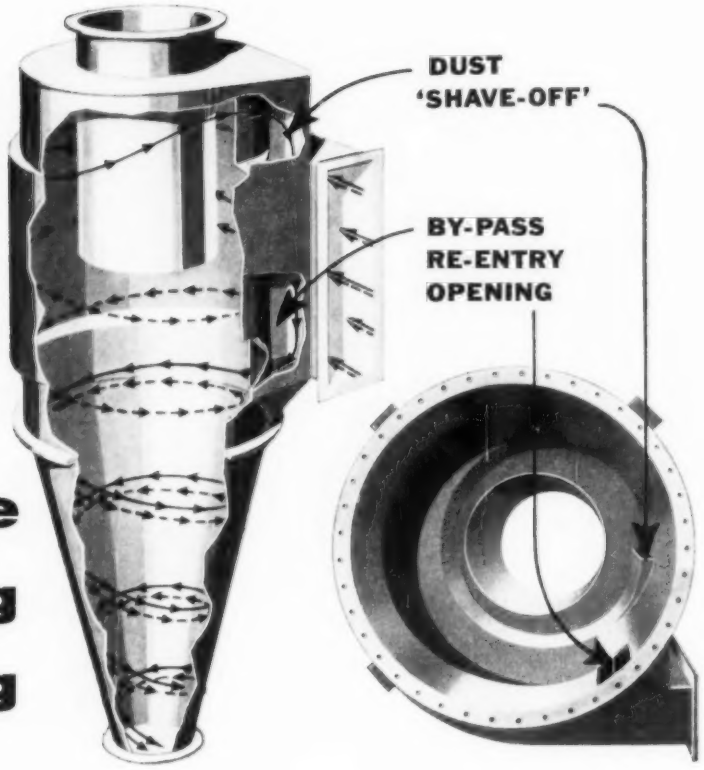

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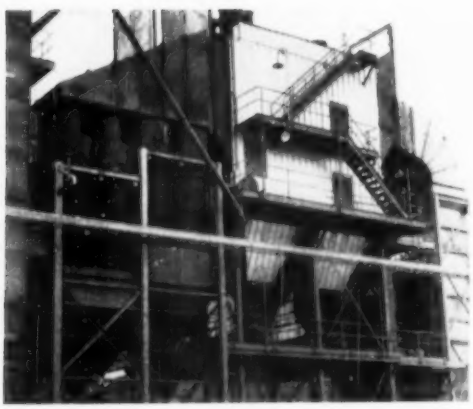

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Editorial

Meetings, Meetings Everywhere

Beginning with the Canadian Sectional Meeting of the World Power Conference in Montreal, September 7–11, 1958, there have followed in rather rapid order the AIEE-ASME National Power Conference in Boston, September 28–October 1, 1958, the Annual Meeting of the ASME, New York City, November 30–December 5, 1958, with a dozen listed sessions on power of which at least half were of direct interest to the power generation industry, the American Power Conference in Chicago, March 31–April 2, and the Instrument Society of America's Second Annual Power Symposium, Kansas City, Mo., May 11–13, 1959. Certainly judging from this impressive coverage the power field is not wanting for attention.

In our role of editor we attend most of these and many other meetings of somewhat allied interest and find that inevitably there are duplications of subject matter among individual meetings. This duplication may well be excused on the grounds that programs must be planned a year or so in advance and there can be no knowledge at this time of other bodies' plannings or for that matter propriety in scheduling. But all too often the same subject will be reported upon at three successive meetings! Even worse the same reports are presented by the same authors or their immediate associates. Obviously some coordination of planning or some central clearing house of authors or some agreement upon general publication is in order.

The nuclear field, once the security wraps were lifted, brought forth a rash of papers and almost as many sponsoring organizations. As time went by the emergence of the Nuclear Congress, the Atomic Industrial Forum and the Nuclear Society offered some hopes for a semblance of order out of this chaotic outburst. Unfortunately the nuclear energy field is still too young and its practitioners and followers too numerous in the traditional founder societies for those bodies to remove themselves from reporting on the activities of nuclear nature which they believe bear upon their member's interests. This is understandable and, we believe, acceptable. Time should correct this when a sharper delineation will have had a chance to assert itself.

The power industry, however, is by most standards a mature and established one and this problem of multiple and repetitive reporting should be a rare one. The growth of special skills and talents as the technology advances can always be expected, to be sure, and room for an expression of these new skills should be allowed within the parent or founder society. Certainly mechanical engineers are keenly alive to the significance and the import of nuclear energy for power generation or instrumentation as an adjunct to power plant automation. In the early days as the broad principles of these newer developments influence the art of power generation the trail blazers of these developments no matter what their background—nuclear scientists or instrument specialists—should be asked to discuss and report upon their contributions before the founder societies. We question seriously, however, if the engineers in the power generation field are so scattered in basic interests that the same material should be presented before essentially power-minded people as frequently as three times in a row.

The ASME, we know, took the stand when it canceled its Spring and Fall meetings that it was setting the stage for fewer meetings and hence fewer papers of higher quality. The individual Divisions were called upon to stimulate conferences serving the relatively narrow and specialized developments within their specific scope of activities. Now with each technical society establishing a similar cell structure the conscientious power generation man is beset with highly polished promotional pieces on the value of a given society's conference to his own and his company's advancement. The fact that he sees on the program the same author on the same subject he has heard before is not enough to dissuade him against the assurance that he will hear something new. Someday he will.

The solution for the multiplicity of meetings must come from within the sponsoring bodies. The last thing we would want to see happen would be an action similar to a boycott of a given technical meeting or its sponsoring body. All have a part to play. Let each define his particular niche and in agreement, one with the other, stay within that niche, presenting the cogent material arising from the activities of those within the niche.

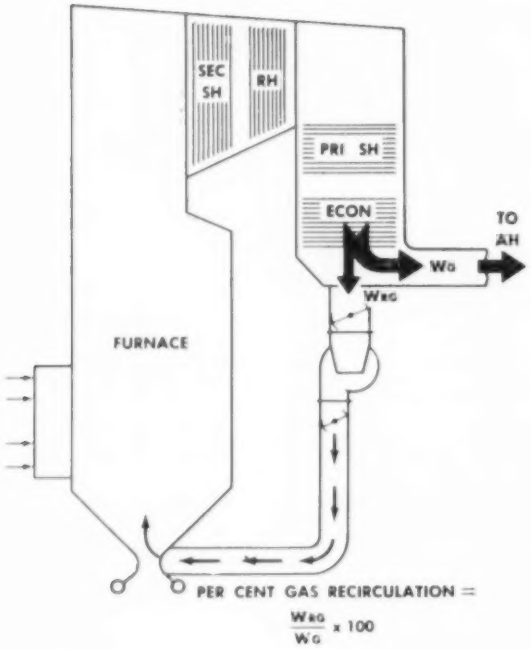


Fig. 1—Gas recirculation applied to hopper bottom radiant boiler

By J. D. ANDREW, JR.,† A. M. FRENDBERG†† and P. M. KOCH†††

Babcock & Wilcox Co.

Gas Recirculation and Its Relation

Setting and controlling the distribution of heat within a present-day large-output steam generator requires considerable design deliberation on the use of one or a combination of several widely used methods. This paper shows the thermodynamic effect of one such method and its application to boiler design and operation.

THE proper proportioning of heat between evaporating and superheating surface is one of the major tasks confronting the boiler designer. With drum type boilers, the distribution of heat determines the quantity of steam generated and establishes both superheat and reheat steam temperatures. In the Universal Pressure once-through boiler this relationship establishes the location of the transition zone and influences the reheat steam temperature. Means must be provided for adjusting and controlling the correct distribution of heat not only at full load but also with changes of load, fuel and cleanliness of the unit.

Improvements in steam power cycle design such as regenerative feed heating, the use of reheaters and the use of higher operating pressures and temperatures, have resulted in greater fuel economy and have also changed the relative proportions of heat required for evaporating and superheating. The desire to maintain steam temperatures over a wide load range, again to increase fuel economy, further complicates the control of heat distribution. Thus, in the design and operation of modern steam generators, methods for setting and controlling the distribution of heat demand considerable attention.

Various means are available for accomplishing this purpose. The most widely used methods are:

1. Steam attemperation
2. Excess air control
3. Radiant superheaters and reheaters
4. Burner arrangement and manipulation
5. Gas bypassing
6. Multiple furnaces with selective firing
7. Gas recirculation

The Babcock and Wilcox Company has used all of these methods, singly or in combination. Each method has its unique advantages to both the designer and the operator. The results of ten years of experience with over 220 units have shown that gas recirculation is one of the most attractive of these methods from both economic and operational viewpoints.

Definition of Gas Recirculation

Gas recirculation is defined as the method by which gas from the boiler, economizer or air heater outlet is reintroduced to the furnace by means of a suitable fan and ducts. Fig. 1 shows a typical application of recirculated gas on a hopper bottom radiant boiler. In most instances the gas is obtained from the economizer outlet. The point

* Presented before the American Power Conference, Chicago, Ill., April 2, 1959.

† Executive Engineer. †† Proposition Dept. Coordinator. ††† Manager New Products Examination.

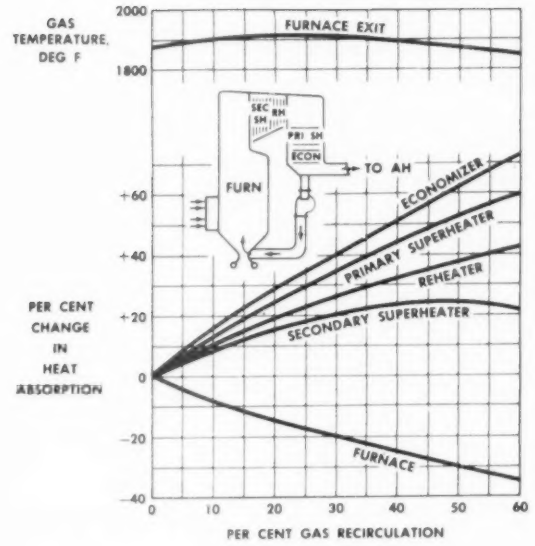


Fig. 2—Effect of gas recirculation into hopper

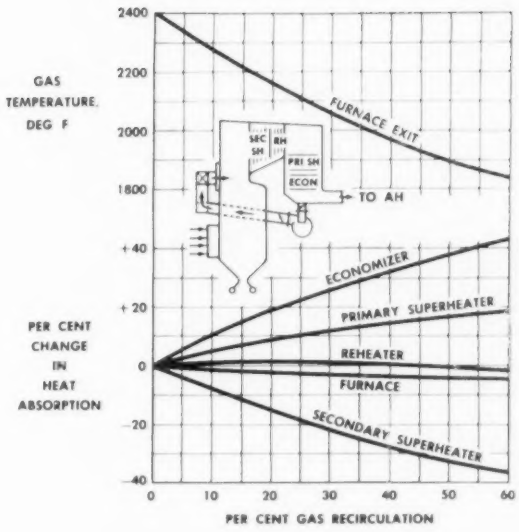


Fig. 3—Effect of gas recirculation into furnace exit

to Boiler Design and Operation*

of reintroduction is dictated by the effect which is desired and, preferably, the recirculated gas should be introduced into the furnace in such a manner as to avoid interference with the combustion of the fuel. The amount of recirculated gas is generally expressed as a percentage of the gas that remains after the point of take-off of the recirculated gas (Fig. 1).

While gas recirculation may be used for several purposes, its basic function is to provide a means of altering the heat absorption pattern within a steam generator in a manner advantageous to both designer and operator. Gas recirculation has the special advantage of providing a means of heat absorption adjustment which may be used both as a design factor in initial surface arrangement and as a method of controlling the heat absorption pattern under varying operating conditions.

An important feature of gas recirculation is that its use changes only the pattern of heat input through a boiler and has a negligible effect on the total boiler heat absorption, the gas weight up the stack and the boiler efficiency.

Thermodynamic Effect of Gas Recirculation

The thermodynamic effect of gas recirculation depends upon the amount of gas recirculated, the location of gas introduction and the furnace rating.

Fig. 2 shows the variation in heat absorption with recirculated gas introduced into the hopper. This method of gas introduction produces a marked reduction in furnace absorption and increases the absorption of the convection section. The total heat absorption remains unchanged.

Furnace heat absorption is primarily a function of the gas temperatures and gas temperature patterns throughout the furnace since the heat is mainly transferred by radiation. Hence, the introduction of recirculated gas into the furnace hopper reduces furnace absorption by altering the gas temperature pattern.

The major portion of the heat transferred in the superheater, reheater and economizer is transferred by convection which depends on gas temperature and gas flow. Both are affected by gas recirculation. Therefore, when the gas flow through a convection bank is increased by gas recirculation, the amount of heat transferred may increase, decrease or remain unchanged depending on the changes in the relationship between gas temperature and gas weight entering the bank. Fig. 2 illustrates a condition in which the gas temperature entering the secondary superheater (furnace exit temperature) is relatively unchanged by gas recirculation. Increasing the amount of recirculated gas, therefore, increases the heat absorption in the secondary superheater. The heat absorption in the reheater, primary superheater and economizer is also increased with the greatest increase occurring at the cold end of the unit. This is a typical example of how the convection pass heat absorption pattern is varied by gas recirculation.

While gas recirculation into the hopper always reduces furnace heat absorption, its effect on furnace exit gas temperature depends mainly upon furnace rating. The furnace exit gas temperature may increase, decrease or, as shown in Fig. 2, be essentially unchanged by gas recirculation. In general, recirculated gas introduced in

the hopper will decrease the furnace exit gas temperature of a unit operating at high furnace loading, and increase this gas temperature at low loading.

Fig. 3 illustrates the effect of introducing recirculated gas at a point near the furnace exit. Since the portion of the furnace in which the bulk of heat absorption occurs is unaffected by this method of gas recirculation, the furnace heat absorption is decreased only slightly. There is, however, quite a large decrease in furnace exit gas temperature, caused by dilution of the hot combustion gases with colder recirculated gas.

In the case of gas introduced near the furnace outlet, the reduction in furnace exit gas temperature is usually sufficient to overbalance the effect of gas weight increase and the heat absorption in the secondary superheater is decreased. The effect of gas recirculation on the reheater, primary superheater and economizer follows the pattern that was shown in Fig. 2, with the greatest change in heat absorption occurring at the cold end.

Figs. 2 and 3 illustrate the effect on heat distribution and gas temperature of introducing recirculated gas either into the hopper or at a point adjacent to the furnace exit. Introduction of gas at intermediate points will result in heat absorptions and gas temperatures between those shown. In order to show the effect of gas recirculation only, Figs. 2 and 3 have been based on constant firing rates.

In summarizing the thermodynamic effects of gas recirculation, the following items are of importance:

1. Gas recirculation always reduces heat absorption in the furnace, the amount of reduction being mainly affected by the location of the point of gas introduction.

2. Furnace exit gas temperature is reduced by recirculated gas introduced near the furnace exit but may be increased, decreased or unchanged by gas entering the lower part of the furnace.

3. Gas recirculation always increases the total heat absorbed by the convection section, the amount of increase depending on the location of gas introduction. The heat pickup of individual convection sections may increase, decrease or remain unchanged depending on their position in the gas stream.

Mixing of Recirculated Gas and Combustion Gas

To obtain the desired effects when using recirculated gas, the gas must be properly introduced into the furnace.

When gas is introduced below the burners, it is usually supplied through the hopper or, in flat floor units, through the rear wall. In both these cases, the gas is introduced at a relatively low velocity.

Recirculated gas introduced above the burners must be injected in a manner that will achieve full mixing as quickly as possible with a minimum of pressure drop. A research program designed to establish the variables affecting mixing and their proper relationship for economical application has been conducted at The Babcock and Wilcox Company's Research Center on many types of furnaces. These studies have shown that the most important variables are gas mass flow through the ports, port spacing, port shape, percentage of recirculated gas and the furnace configuration.

As a result of these investigations, an arrangement of port sizing and spacing has been developed by which it is possible to achieve excellent mixing with a minimum of pressure drop.

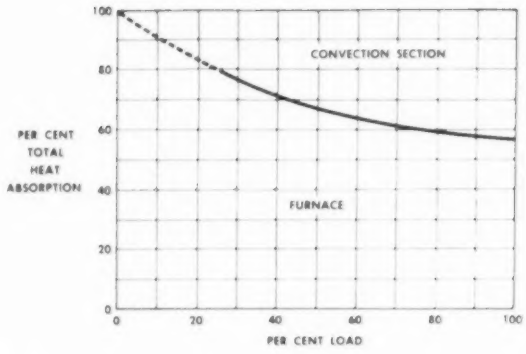


Fig. 4—Increase in furnace heat absorption at low loads

Application of Gas Recirculation to Design and Operation

Depending on the type of boiler and the point of introduction into the furnace, gas recirculation can be used to control:

1. Steam Temperature
2. Gas Temperature
3. Furnace Heat Absorption

1. Gas Recirculation for Steam Temperature Control

The most widely used application of gas recirculation is for the control of superheat and reheat steam temperature.

As boiler load is reduced the furnace absorbs an increasingly larger percentage of the total heat (Fig. 4). In a drum type boiler with a convection superheater this change in the distribution of heat between evaporating and superheating surface results in low steam temperatures at low loads. Since gas recirculation into the lower part of the furnace reduces furnace absorption and increases convection absorption, it is ideally suited for use as a method for maintaining steam temperatures.

Fig. 5 is a typical drum type boiler performance curve and illustrates how the use of only small quantities of recirculated gas can control steam temperature over a wide load range.

In the case of a Universal Pressure once-through boiler where superheated steam temperature is controlled by firing rate, gas recirculation may still be used to control reheat temperature at low loads.

When gas recirculation is used to control steam temperature, the control procedure will vary depending on the type of firing, the desired control range, and the use of other control methods such as steam attemperation, gas bypassing or radiant superheaters. A typical application on a hopper bottom drum type boiler with a reheater in series with the superheater, would be to control reheat temperature with gas recirculation and control superheat temperature by a small amount of spray attemperation.

2. Gas Recirculation for Gas Temperature Control

A second important application of gas recirculation is for the control of furnace exit gas temperature. The relationship between the amount of heat required for evaporation and that required for superheating has been

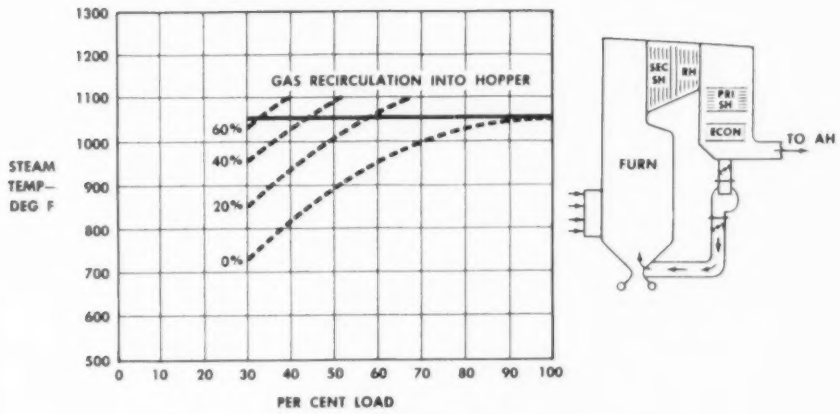


Fig. 5—Steam temperature control of natural circulation boilers

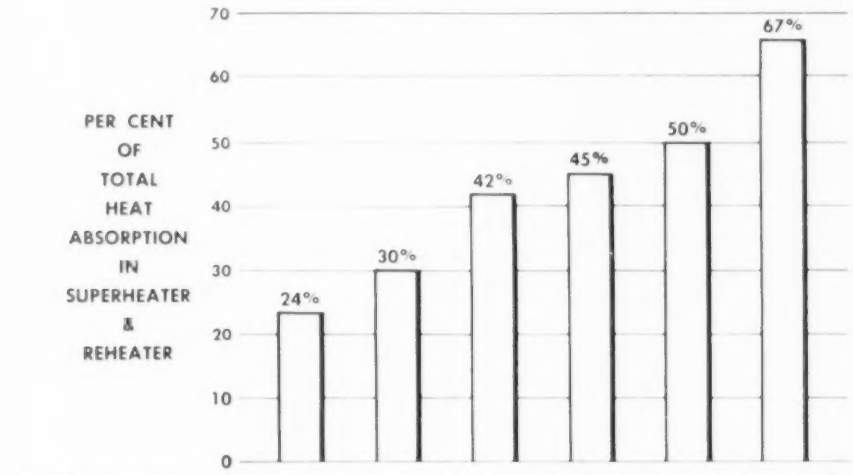
continually changed by advances in the design of steam power cycles. Fig. 6 shows that 50 per cent of the total heat is absorbed in the superheater and reheater of a modern 2400 psig, 1050–1050 F boiler, as compared to 24 per cent in a 900 psig, 900 F plant.

In boilers with convection superheaters and reheaters, these increased absorption requirements could be satisfied by increasing the gas temperature entering the convection section. Fig. 7 shows the required gas temperature entering the superheater for units with present day utility steam conditions. The necessity for placing the superheater and reheater in zones of high gas temperature introduces major problems in obtaining suitable materials, providing adequate supports and preventing ash fouling, corrosion and creep of tube surfaces.

With the use of gas recirculation these problems can be avoided by supplying the convection section with a sufficient amount of heat at a low gas temperature. Introducing recirculated gas into the furnace near the outlet (Fig. 3), will reduce the gas temperature while only slightly affecting the furnace absorption or total convection pass absorption. Thus it is possible to design a boiler for high pressures and temperatures by using gas recirculation to reduce furnace exit gas temperature to a satisfactory level and supply the required heat to the convection section by means of a higher gas weight and lower gas temperature. This arrangement results in a very economical furnace.

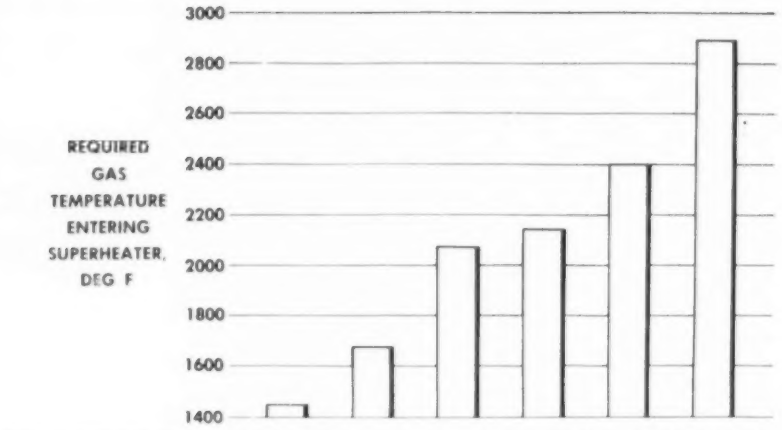
Gas recirculation for gas temperature control may be applied to either drum type or once-through boilers.

Fig. 3 shows that the use of gas recirculation for gas temperature control reduces secondary superheater absorption. This results in reduced alloy requirements in the high temperature steam zones because the heat is



PRESS.—PSIG	900	1500	1850	2100	2400	3500
SH TEMP—DEG F	900	1000	1000	1000	1050	1050
RH TEMP—DEG F	—	—	1000	1000	1050	1050/1050

Fig. 6—Distribution of heat absorption



PRESS—PSIG	900	1500	1850	2100	2400	3500
SH TEMP—DEG F	900	1000	1000	1000	1050	1050
RH TEMP—DEG F	—	—	1000	1000	1050	1050/1050

Fig. 7—Required gas temperature entering superheater

transferred at a lower temperature level.

While the method of applying gas recirculation for gas temperature control may vary with the type of unit, the usual procedure is to recirculate a fixed amount of gas at full load and then decrease the amount at lower loads when there is no longer a need for reducing furnace exit gas temperature.

3. Gas Recirculation for Furnace Heat Absorption Control

In a manner similar to that which occurs in a drum type boiler, the furnace of a Universal Pressure once-through boiler will absorb a larger percentage of the total heat as the load is decreased. In a drum type boiler, this will result in a decrease in steam temperature. In a once-through boiler of the Universal Pressure type, the superheater outlet temperature is controlled by firing rate and variations in the heat absorption pattern will only change the fluid temperature at intermediate locations. So, although there is no necessity for controlling the superheater outlet steam temperature, it is sometimes desirable to control the location of the transition zone and to limit steam temperatures at certain locations.

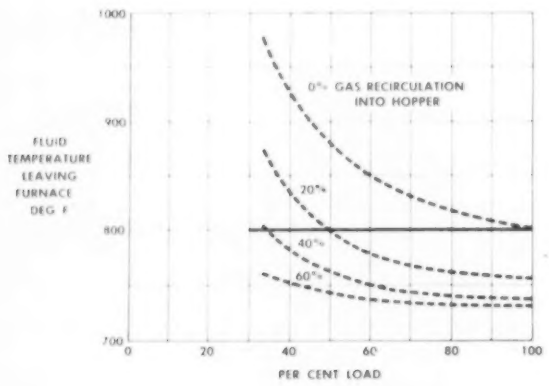


Fig. 8—Furnace absorption control of a 3500 psi universal pressure boiler

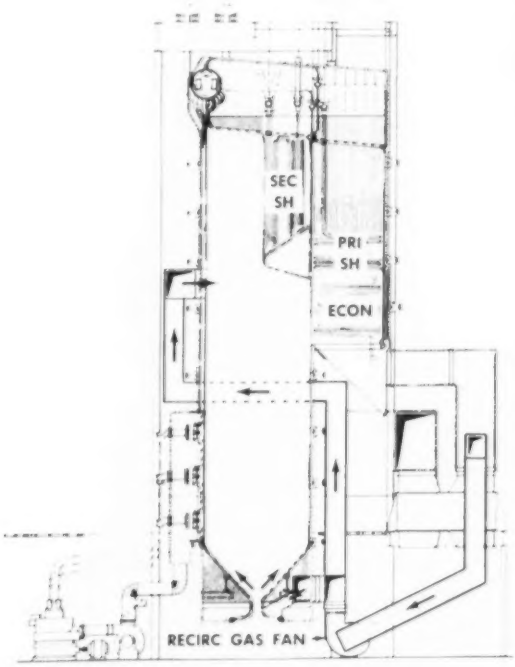


Fig. 9—Gas recirculation for gas temperature and steam temperature control

Fig. 8 shows how increased furnace heat absorption at low loads can increase the fluid temperature leaving the furnace of a Universal Pressure boiler and illustrates the use of gas recirculation into the hopper to maintain a constant fluid temperature.

Although the use of gas recirculation for controlling furnace absorption in a once-through boiler serves a different purpose, it is functionally identical to the use of gas recirculation for controlling steam temperature in a drum type boiler. In both cases the recirculated gas is used to shift the absorption pattern in such a manner as to decrease furnace heat absorption and increase the convection pass heat absorption.

The application of gas recirculation to a specific job need not be limited to a single objective but may be used for a combination of several purposes. Figs. 9, 10 and 11 illustrate three typical applications of gas recirculation.

Fig. 9 illustrates a drum type boiler which takes full advantage of the flexibility of gas recirculation. By introducing the gas at different locations, it can be used to control both steam and gas temperature. Thus, gas recirculation is used at high loads to reduce furnace exit gas temperature and at low loads to increase superheated steam temperature. This arrangement results in an extremely wide control range.

Fig. 10 shows a drum type cyclone furnace boiler which uses a combination of gas recirculation for gas temperature control radiant reheater platens, and steam attemperation. This combination of absorption control methods results in a compact unit with a good control range.

Fig. 11 illustrates the use of gas recirculation on a cyclone furnace Universal Pressure boiler in which gas recirculation is used for three purposes—gas temperature control, reheat control and furnace absorption control. Recirculated gas is introduced near the furnace outlet at full load thus permitting the use of an economical furnace while limiting the furnace exit gas temperature to avoid ash fouling. As load is decreased on the unit, the gas is introduced at a lower level which decreases furnace heat absorption while increasing the heat available to the convection section. At low loads, therefore, the fluid temperature leaving the furnace is controlled within the desired limits, and the gases entering the reheater have sufficient heat to maintain reheat steam temperature over a wide load range.

Boilers similar to those shown in Figs. 9, 10 and 11 have the following advantages:

1. Low tube and support metal temperatures during both start-up and operation, resulting in low maintenance costs.
2. Wide control range of steam temperatures.
3. Flexible operation with varying fuel characteristics and multiple fuels.
4. Low superheat pressure drop due to locating the superheater in low heat input zones.
5. Economically sized units with resulting decrease in steel, foundation and building requirements.
6. Good control of ash fouling and less soot blower operation and maintenance.
7. Safe, fast start-up resulting from ability to limit gas temperatures to superheat surface.

Gas Recirculation System Availability

No advances in engineering are without their field development troubles. Problems which beset the initial gas recirculation installations were (1) fan and duct overheating, (2) fan vibration, (3) fan erosion and (4) gas

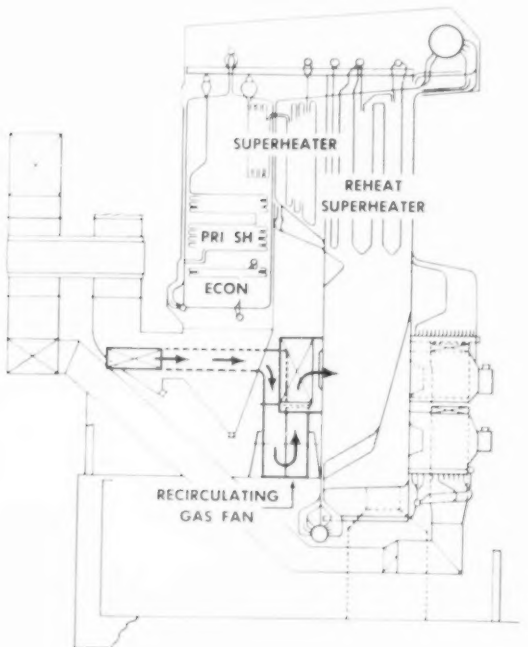


Fig. 10—Gas recirculation for gas temperature control

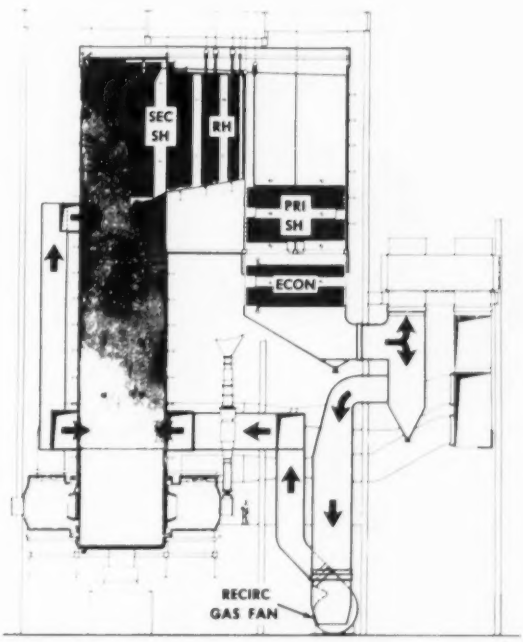


Fig. 11—Gas recirculation for gas temperature control, reheat control and furnace heat absorption control

port pluggage, not necessarily in order of severity.

Difficulties were experienced on several early jobs with overheating of both the gas recirculating fan and its connecting ducts by back-flow of gases and by radiation from the furnace. Improvement in design and controls plus proper fan sizing have eliminated these troubles.

Due primarily to inadequate design of fan, shaft seals and foundations, some problems were encountered with rough fan operation. These have been solved by improved designs.

Fan erosion has occurred on several pulverized coal fired units due to poor gas take-off locations or to continuous fan operation at high loads with no dust collector. On jobs where the gas fan is used for superheat control only, experience indicates that the proper location of the gas take-off will satisfactorily reduce fan erosion. On pulverized coal fired units which employ gas temperature control at full load a dust collector is preferred.

Gas port pluggage was experienced on several of the initial slag tap installations. This problem has been eliminated by improved port design and location and by proper use of soot blowers.

The experience gained on these early installations has resulted in the design and installation of gas recirculating systems which have virtually 100 per cent availability.

Conclusions

The use of gas recirculation is one of the most attractive methods available for obtaining the proper proportioning of heat within a steam generator. Its use permits great flexibility in design and its successful application to practical operation has been amply demonstrated.

Gas recirculation has provided a method of obtaining and controlling the high steam pressures and temperatures which are necessary for good fuel economy. In the future, as the inherent design and operational flexibilities of gas recirculation are more fully utilized, it should contribute even more significantly to the continuing economic advancement of the steam power cycle.

Coal Bunker Explosions

At the recently concluded American Power Conference in Chicago **W. W. Hagnauer,** Commonwealth Edison Co. and **K. W. Hamming,** Sargent & Lundy, discussed the cause and prevention of coal-bunker explosions.

Fortunately, there have been relatively few bunker explosions reported in recent years. Two such explosions, however, have occurred in stations of the Commonwealth Edison Co. within a period of seven years. These explosions were of such serious magnitude that the authors' companies have carried on several investigations of the causes of bunker explosions and the possible means of preventing them. Investigations have consisted of an exploration of the circumstances of the specific explosions as well as a general survey of the coal handling facilities at all of the company's stations. The survey covered coal handling operating and maintenance practices as well as a review of the design of the facilities. This paper discusses the general conclusions revealed by these investigations.

As to the prevention of explosions of the nature described, one of the most important design considerations is to provide an adequate ventilating system. The system, or systems, should ideally accomplish three things: (1) continuous removal of explosive coal gases from the bunker, (2) elimination of coal dust in the coal handling conveyor rooms by adequate ventilation of the coal transfer points and its emission from the bunkers during a filling operation, (3) provide operating personnel with reasonably comfortable working conditions to encourage good housekeeping and regular inspection.

Subsequent to the first bunker explosion, tests were made to establish the required amount of ventilation to prevent accumulation of explosive gas quantities. It was determined that a continuous quantity of about 2 cfm of air per each ton of stored coal was required to keep the methane well below explosive limits.

It is obvious that the more adequate the system, the less troubles the operator will have. At best, however, coal handling is a difficult problem and no system can be successful without good operation and maintenance. The most important obligation of the operator is to establish a regular bunker cleaning or trimming schedule. This schedule should require dropping the level or trimming often enough so that bunker fires do not occur.

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American Power Conference in Review—II

LAST month's issue of COMBUSTION carried a major portion of the American Power Conference papers held to be of value to the readers of this magazine. There were, however, so many that in the interest of space the complete meeting report was divided into two parts and the following was held over for this issue.

Once-Through Boilers

A special symposium was held on the subject of once-through boilers for subcritical pressure. Four papers were presented.

E. M. Powell, Combustion Engineering, Inc., headed off the session with the paper "Design and Operating Characteristics of Steam Generating Equipment."

The Monotube Steam Generator is basically of the once-through principle and can be designed for operation either above or below the critical point. At subcritical pressures certain modifications are possible to take advantage of the presence of water and steam mixtures, and provide for the separation of water from the steam. Feedwater from pumps passes through high-pressure heaters, feedwater regulating valves, economizer, evaporating section to the boiler water separator, then through superheater to the turbine.

Saturated water is returned from the separator to the high pressure heaters with some taken off for blowdown to control the steam purity and remove solids from the system as needed. Under normal operating conditions the quantity of water return is regulated automatically to approximately 4 per cent of the feedwater flow.

Part of the feedwater bypasses the first part of the unit and is injected at the inlet to the finishing superheater to control the final steam temperature.

The water separator insures dry steam at constant temperature at the inlet to the superheater under all types of operating disturbances. Coupled with injection at the small finishing end of the superheater, this results in an extremely stable and sensitive temperature control system.

No intermediate headers are used in the evaporating section. This eliminates the problem of trying to distribute mixtures of water and steam uniformly from a header into a multiplicity of tubes and insures equal velocities and temperatures or steam quality in all of the parallel tubes.

In a once-through boiler without recirculation, the velocity of water and steam is directly proportional to load. To adequately protect the heating surfaces at low load requires high velocity at full load and as a consequence high pressure drop. To avoid excessive pump power, most once-through boilers in Europe have been limited to a turn-down ratio of about 3 to 1. Distribution stability and velocity are inadequate below 30 per cent load to fully protect the unit.

Without the water separators these units would be subject to the same limitation. However, with this design a minimum flow of 30 per cent can be maintained through the furnace circuits where heat transfer is the greatest. The balance of water in excess of the steam generation can be returned to the feedwater system through the water separator and recycled through the evaporator section. In this way the unit can be operated at 10 per cent load if desired with full protection.

To summarize then a water separator is not a necessary part of a once-through system and in fact cannot be used at supercritical pressures. It has been incorporated into these particular units to achieve certain important advantages: (1) provide means for blowdown and removal of contaminants, (2) provide constant steam temperature to the superheater during normal operating conditions, (3) provide heat to feedwater during startup, (4) provide protection when operating at minimum load, (5) prevent water discharge to superheater during a hot restart, (6) provide means for purging evaporation section by increasing water flow to dissolve solids which can then be removed by blowdown without affecting steam conditions.

The Monotube once-through boilers involved many new design considerations to conform to American practice:

(1) They are larger in size and higher in pressure than any once-through units previously built.

(2) They are the first to utilize tangent tube walls and skin casings in the furnace construction.

(3) They are the first monotube units to use tilting tangential burners for reheat temperature control.

(4) They are the first large units built by the author's company, of their own design, using a portion of the furnace wall as a superheater.

J. G. Miller and **J. S. Bartman,** Metropolitan Edison Co., followed with the paper, "Major Design Features and Early Operating Experiences, Portland Generating Station, Metropolitan Edison Co." The choice of steam conditions was based on the desire to utilize as high an initial pressure as could be justified for the size of the

unit, but to limit the temperature to 1050 F to avoid the necessity of using austenitic steam piping. In the initial study, 3500 psi was considered, but it developed that the projected unit size was too small to justify this pressure. The final choice was 2400 psi nominal pressure, 1050 F superheat temperature, and 1050 F reheat temperature. The 1050 F reheat temperature over 1000 F appeared to be a break-even proposition at today's fuel cost and the higher temperature was chosen in the interest of achieving a lower heat rate and anticipated long range economic advantage.

The nominal operating pressure of 2400 psi will be maintained until turbine inlet valves are wide open at which time the controls will be reset to increase to and maintain an operating pressure of 2520 psi in order to get additional capacity from the unit.

In general, the once-through boilers are similar to conventional units in appearance except there are no large horizontal drums. There are, however, two water separators—one in each circuit. These are located at the front and top of the unit. The bypass water separator which permits bypassing dry steam through the reheater, is also located near the top. It should be noted that considerable radiant superheater surface is provided both in the furnace wall and in the form of pendants above the furnace. The reheater is all convection surface and immediately follows the pendant superheater section.

The furnace is fired with conventional tangential burners—one group of four at each corner. Flow through the waterwalls is both up and down and this point the author commented bore on later discussion of the experience with the wall blower operation.

The unit was synchronized for the first time on October 5, 1958, and ran at various loads up to 150 Mw until October 18, 1958, when it was shut down for bearing inspection. It was placed in commercial operation on October 29, 1958, and in successive steps the capacity was increased to 165 Mw. The main difficulty in increasing the output of the unit during this period and after each shutdown since has been related to the control of silica in the steam admitted to the turbine. This situation has been improving, and at present requires less than 24 hours after start-up for the silica to reach acceptable limits.

In general, the operation of the unit has been very much as anticipated, although we are not at present utilizing the full potential of the unit for rapid starting and fast loading. This situation, however, is not the result of equipment capability, but more a matter of operator training and control adjustment.

The Sulzer controls are high quality equipment and have performed in a reliable manner. In Europe, regular mineral oil is used in this hydraulic mechanism, but not wishing to risk the danger of fire, Metropolitan Edison Co. desired to use a non-flammable synthetic fluid.

From the beginning it was apparent that a Monotube boiler is sensitive to changes in furnace conditions. Operation of any one of the wall deslaggers resulted in considerable change to the feedwater and steam flow in the unit, and 15 to 20 minutes would be required for the flows to return to normal. This situation was aggravated when the deslaggers were used at full load because the turbine control valves reached their wide open position and control of the steam pressure was lost. Similar upsets occurred on temporary loss of coal feed to a mill. This boiler has relatively small storage capacity, so that losing mill feed even for a short time results in considerable loss of load. As of now this situation has been greatly improved by the refinement of the feedwater control so that the problem today is not a serious one although further improvement will be most welcome.

The level in the water separators is indicated in the control room by a Bailey instrument which is connected to the pressure taps used by the automatic level controller. This instrument was calibrated by a conventional water column prior to initial operation but tended to indicate a zero level in the separator in operation when it was certain, from other indications, that a level existed. Several recalibrations did not correct this situation. After considerable thought on this problem, it is the general opinion that this condition is due to vortex and centrifugal action in the separator, that no definite level exists, and therefore no calibration could be obtained using a static water column. The meters were then set so that the level indicated corresponded roughly to levels known to exist. The meters therefore do not indicate exact levels in feet, but do show relative changes and give the operator an idea when approaching dangerous levels. Since this really is all that is necessary, the indication of levels is now considered to be satisfactory.

J. D. Williamson and **R. F. Andres,** The Dayton Power and Light Co., then discussed the "Operation and Water Conditioning of Unit No. 4 Tait Station." This paper was concerned principally with feedwater and steam as affected by a Monotube boiler. One of the highlights of this installation has been the performance of the Sulzer feedwater control. Severe load drops both planned and accidental have occurred and the control has given excellent performance. The absence of a drum and attendant concern about water level is a boon to the operators' peace of mind.

All large automatically controlled valves in the feedwater and steam system up to the turbine stop valve were made by Sulzer Brothers. After increasing the clearance between the stem and guide bushing of some of these valves, their performance has been satisfactory.

When certain emergencies occur, one set of fans and all pulverizing mills except one trip automatically. The boiler then operates on the bypass system and is available for the quick restarting of the turbine. The feature of leaving one mill in operation under this condition was added by the authors' company.

A coal of 11,250 Btu, 8 per cent M, 3 per cent S and 12 per cent ash is being burned successfully in this boiler.

A heat reclaimer employing a finned tube economizer is located between the dust collector and the induced draft fan. A similar device is located between the forced draft fan and the air preheater. Water is circulated between the two economizers. Soot blowers on the gas side would not keep the finned tubes clean during winter operation and a water washing device was installed. When allowance is made for the less-than-expected exit gas temperature from the boiler, the heat reclaimer is doing a good job.

Based on European experience with boilers of this type, the following feedwater requirements were set up:

Total solids	0.5 ppm maximum
pH	8.8–9.2
Dissolved oxygen	0.007 ppm

While no limits were established for iron and silica contents, these constituents must be maintained as low as possible to insure prolonged periods of trouble-free boiler and turbine operation.

Feedwater of greater purity than specified for this unit has been obtained for many years in our stations by maintaining condenser leakage at minimum values and supplying makeup water from evaporators. To supply the high purity feedwater for this new type boiler, the following changes from normal practices were made: (1) condenser tubes were welded and rolled, (2) the condenser air removal section was tubed with stainless steel, (3) an evaporator was specified to provide makeup water containing a maximum of 250 ppb total dissolved solids, (4) the evaporator was installed in the cycle to serve as a bypass water purifier for the concentrated boiler-water returns, (5) ammonia to be the only chemical treatment.

In operation of this boiler to the present time there has been no detectable condenser leakage. Leakage is monitored by continuous recording of the acid conductance of the condensate leaving the condenser and the conductivity values have been the same as those obtained for reheat steam samples within limits of measurement. Sodium and silica contents of the condensate also are the same as measured in the reheat steam within the limits of reproducibility of these determinations.

The stainless steel tubes were installed in the air removal section to minimize potential corrosion from high oxygen and ammonia contents normally present in the condensate adjacent to the tube sheet. These tubes were rolled but not welded and have not presented any leakage problem.

The condenser was not chemically cleaned and the amount of iron oxide sloughed off from the condenser shell resulted in rapid fouling of the condensate pump strainer screens during the first few months of operation.

The evaporator was purchased with a guarantee to produce distillate not to exceed 250 ppb total dissolved solids. Experience with similar evaporators in our stations indicated that it should produce makeup water containing 15–50 ppb total dissolved solids in normal day-to-day operation. Despite the fact that little attention has been directed to proper evaporator operation, the evaporator has produced vapor with a total solids content in the range of 100–150 ppb. In a recent paper, Lawrance and Ziobro point out that a similar evaporator, properly designed and operated, can produce vapor containing less than 10 ppb of total dissolved solids in continuous operation. Two important factors in obtaining these purities are the determination of the proper operating level and the proper location of the splash baffle. A testing program on our evaporator to evaluate these factors is currently in progress and we anticipate obtaining similar vapor purities in the near future.

The evaporated makeup water to this unit has furnished sufficient natural ammonia to maintain the desired pH range of 8.8–9.2 throughout the steam feedwater cycle. Fortunately, the ammonia in the well water supplied to the evaporator is in the proper range and there has been no need to furnish any supplementary chemical feed of ammonia.

The evaporator has consistently produced vapor with a silica concentration in the range of 0–3 ppb. It is not surprising that silica values in the steam from the high-pressure boiler have usually been in the very low range of 7–10 ppb.

The operation of the evaporator as a bypass purifier for the concentrated boiler-water returns has been very successful. Since the evaporator can handle 25 per cent of the normal concentrated boiler-water returns, purification of the cycle is rapidly accomplished after periods of excessive contamination or after boiler outages.

In the start-up of this Monotube boiler from a cold condition, water is circulated through the boiler and bypass system at a flow rate of 30 per cent of that at full load. During this recirculation period the water leaving the condenser contains 10–20 ppb of oxygen, but the water is reaerated flowing through the deaerator. This introduces considerable oxygen to the cycle during start-up and could result in boiler corrosion. Installation of a vent from the deaerator back to the condenser should eliminate this problem. The deaerator produces feedwater containing less than 2 ppb of dissolved oxygen during normal operation.

Evaporated makeup water is fed directly to the deaerator permitting the removal of any excess carbon dioxide in the makeup water. The deaerator removes practically all of the carbon dioxide and the desired pH range in the feedwater cycle is obtained with a concentration of 200 ppb of ammonia.

Operation and Controls

E. D. Scutt, Leeds & Northrup Co., as part of the Symposium on Once-Through Boilers gave a paper entitled "An Integrated Combustion Control System for Once-Through Boilers." Mr. Scutt pointed out that in considering the application of automatic combustion control to once-through boilers, the following design features and operating requirements are of particular interest in comparison with conventional drum type installations.

1. With the once-through design, the boiler drum and its associated downcomers for recirculation through the evaporating sections of the boiler are omitted. Circulation through the furnace walls and heating surfaces of the steam generator, with once-through design, is directly dependent upon feedwater supply. It is therefore necessary that the automatic control keep the steam demanded by the turbine within the available feed pump capacity. In addition, water supply should be matched closely to firing rate.

2. An external turbine bypass system provides circulation through the steam generating unit during start-up and at minimum turbine outputs or under abnormal operation. With this bypass arrangement it becomes very desirable to coordinate the operation of the boiler and turbine, in order that steam will not be bypassed during normal operation.

3. The time required for water to pass through the boiler unit and be converted to superheated steam, when operating at full load, is between two and three minutes. This time compares with figures ranging from six to ten minutes for conventional drum type boilers of recent de-

sign. This residence time is only one of a number of factors which affect the relative storage capacity and response characteristics of a boiler.

4. Recent tests at Dayton indicate that the available energy storage capacity of the Tait unit is approximately 60 per cent of that observed in two dissimilar drum type boilers of recent design in this country. The Tait unit has between two and three times the equivalent storage reported for units of European design. The automatic combustion control is concerned vitally with the relative storage and the associated dynamic response characteristics of the boiler. It is important that the control system be arranged to accommodate the reduced storage capacity which is available in once-through units.

An early review of the foregoing conditions indicated that the boiler and turbine should be considered as an integral unit, with a coordinated control to regulate both (*a*) the energy input to the boiler to provide the described desired electrical output from the generator, and (*b*) the steam supply to the turbine. With such an arrangement, the control system is responsible for regulating the turbine governor.

Initial operation of the controls at Tait and Portland has confirmed the anticipated results of earlier analysis and simulation studies. The Direct Energy Balance method of operation provided with the integrated combustion control system the author described has proved desirable for once-through boiler-turbine units. The pertinent plant operating charts included were from the Tait unit and showed operating results with complete automatic control during a normal load drop and pickup on the morning of February 14, 1959.

C. D. Birget and **J. H. Kline,** Commonwealth Associates, chose for their title "Which Enclosure Shall It Be?" for their paper on a study of varying degrees of power plant enclosures. This study was undertaken to determine the initial costs that could be saved by varying the degree of the power plant enclosure from a fully enclosed type steam electric generating plant to a completely outdoor plant as would be built for a utility farther south. This study is predicated on certain basic design criteria being established as follows:

1. This will be a high capacity factor plant. (Average—0.63 for 35-year life.)

2. This plant will be designed for relatively high cost fuel. (Average—53 cents/MBtu; 40 cents/MBtu at initial operating date and measuring 2 per cent per year for 35-year period.)

3. Regardless of the climatic conditions, there will be no sacrifice in station reliability as a result of varying the amounts of enclosures.

4. This will in no way be a minimum facility. The power plant will be complete in all respects except that certain exterior portions of the building will be omitted as described in the details of this paper.

5. That a type of construction which makes use of insulated sheet metal walls with an insulated sheet metal tar and gravel roof with a temporary end wall of uninsulated sheet metal be the base for the study.

The authors advanced several designs, one each for three sharply different areas of the country, and approached each design with a number of probing demands. In conclusion it might be said for the conditions assumed for this study, it has been shown that the building enclosures proposed in each case can be justified.

One figure the authors submitted showed that there can be substantial savings using the totally outdoor design in areas where the yearly average temperature is in the 65-F range and in which the turbine-generators do not have to be protected for the extreme temperatures.

When the capacity factor is decreased, the equivalent investment cost will also be decreased, thus for a peaking type plant with a low capacity factor it may be difficult to justify any type of enclosure.

In the areas where low cost fuel is available, the equivalent investment cost due to heat loss would be decreased and would affect the summary total.

For each geographical area, with each set of design conditions, with the fuel costs and the capacity factors established, an evaluation of this type must be made to determine the economic plant design.

The interesting story of the "Evolution of Automation" was presented by **F. A. Ritchings** and **W. A. Summers,** Ebasco Services. After a few comments on the growth of the power generating plant of today the authors pictured the present in this way. "Between Edison's first plant and modern central station there is over 50 years of development of automatic devices to protect equipment against damage, to reduce personnel hazards, to improve reliability and availability, to improve efficiency and to reduce operating manpower. The major developments include independent, self-regulating loops, automatic protective equipment and metering."

These controls or sub loops do not form an integrated or interdependent system but operate independently of one another. Coordination, equipment monitoring and operation of equipment used infrequently are the function of the human operator.

The decisions as to equipment starting and stopping, control readjustment are based on information gathered by visual equipment inspection, hand logged data, human scanning of board readings and human correlation of such data.

Analysis has indicated that plant efficiency and reliability could be increased and operating manpower decreased by supplementing humans with machines. This could be accomplished in two steps—the first step; data gathering and correlation and calculation to produce information, which would provide substantial benefits; and the second step; correlating information to produce decision and execute these decisions which could produce even greater potential benefits.

The first step is limited to the installation of scanning, logging and results computation equipment to assist the operating staff. The second step involves expansion of the equipment required for the first step so that the decision-making equipment replaces the human operator. This is the sequence in which automation of steam electric production plant was developed.

The authors present concept of automation includes:

1. Starting the plant equipment from a cold or hot condition after prescribed initial conditions are set up by the operator or maintenance crew. The automatic system would functionally check initial conditions to assure safe operation. All equipment would be started

in normal sequence with each required intermediate condition being satisfied both for the individual piece of equipment and for other affected equipment and for the station as a whole before proceeding to the next step in this starting sequence. This starting sequence would be carried through synchronization and load application up to the desired load.

2. The computer and associated analog controls will operate, start, stop, reposition or adjust the equipment as necessary to follow system load demands while maintaining optimum efficiency for the uncontrolled conditions existing—that is the circulating water temperature, fuel analysis, atmospheric conditions, degree of condenser fouling, etc. This requires efficient modulation of the turbine generator governor to the desired load, boiler fuel and air to desired steam output, boiler steam temperature control system, turbine generator cooling systems and any other controls that must be adjusted as a function of load.

3. The system will shut down the plant, on command, in a safe manner.

Equipment for automation to the extent just described has been purchased by Louisiana Power & Light Co. for their 220-Mw class, gas-fired, Little Gypsy installation. The equipment will be installed for trial operation in 1961.

The authors are continuing their studies on the automation of a pulverized coal-fired steam generator. Work to date indicates areas of greater difficulty in the boiler operation. However, they do not appear insurmountable.

Water Conditioning

This year's Power Conference scheduled four water technology sessions and many papers were offered. Space reasons prevent our abstracting all.

H. C. Farmer, Philadelphia Electric Co., and **S. B. Applebaum,** Cochrane Corp., collaborated on the paper "Two Bed Primary System Solves Mixed Bed Demineralizer Problems at Philadelphia Electric Company Cromby Station."

The Two Bed system was put into operation in August, 1955 and at that time the Mixed Bed system was placed in the secondary polishing position. The Two Bed system has now been in operation for over three years. The combination of the Two Bed and the Mixed Bed polishing has solved the previous problems of decreasing capacity and deteriorated effluent quality. No resin replacement has been made in the Two Bed system.

Up until December 1958 a total of 105,000,000 gallons in 750 runs have been treated by the two bed system. Samples of these resins, after about 670 runs and over three years of operation and after treating a total of 60,000,000 gallons or 420,000 gallons per cu ft of resin, were collected in September 1958 and analyzed in the Cochrane Laboratory. Both the cation and the anion resin seemed to be entirely stable. Only very slight loss of basicity and capacity were found to have occurred for the anion resin.

Therefore, it can be stated that the IRA-400 when used in the Two Bed system in the primary position, has shown no undue fouling by organic matter or loss of basicity or capacity.

In table form, the design capacity was given, both in gallons and in kilograins. Also, three typical runs in 1958, which was the third year of operation, were tabulated which confirmed the laboratory analysis of the anion resin, indicating no appreciable deterioration.

The mixed bed polishing units are regenerated once in two months, treating about 2,000,000 gallons per run. These are long runs and the resin beds are occasionally fluffed during a run to break up packed beds.

The mixed bed units have continued to produce very satisfactory effluent during the last three and one-half years of operation when they were employed in the polishing position without any resin replacement and without any treatment of the resin. During this time, the mixed bed units were occasionally tested in the primary position and showed adequate effluent quality. In December 1958, however, when a prolonged requirement for high amounts of makeup occurred, tests were again made on effluent quality obtainable from these mixed bed units in the primary position. This showed that they could not produce an effluent conductivity below about 10 to 20 mmhos. Normally, the required makeup is about 50 gpm which is easily obtained in series operation. However, to fill boilers rapidly after maintenance, they use parallel operation to obtain over 200 gpm.

Therefore, to be prepared for parallel operation when such peak demands are again required, it was decided to replace the resin in the mixed bed units with IRA-400 for the anion resin and IR-120 for the cation resin.

I. M. Abrams, G. F. Stoneman and **M. A. Roberts,** Chemical Process Co., detailed their "Experience With An Improved Intermediate-Base Anion Exchanger for Problem Waters." As the authors reported, the principal method used until now to eliminate or diminish resin degradation is to treat the water prior to demineralization. A more suitable method of reducing anion resin replacement cost would be to provide exchangers which are less subject to fouling and oxidation. This paper is concerned with an acid adsorbent which the authors feel gives promise of fulfilling this objective.

The established improvements in weak base anion resins lead the authors to look for prospects of lowering resin replacement costs, particularly with problem waters. The polystyrene resins have, in their opinion, proved more stable to the effects of oxidizing agents than the phenolic resins. The newly formulated epoxy-polyamine resins appear to offer a greater degree of stability than has been available heretofore.

Replacement of phenolic or polystyrene weak base anion exchengers, with Duolite A-30B the authors reported has resulted in performance and longevity which have already exceeded those of its predecessors. The principal effects of "aging" in this resin are (1) slight swelling and (2) a decrease in its strong base capacity. Both of these effects appear to be beneficial in operation rather than harmful.

The subject, "High Flow Rate Ion Exchange," was presented by **Joseph Thompson** and **A. C. Reents,** Illinois Water Treatment Co. The power generation field requires water of the highest quality for the following applications: (1) Conventional subcritical boilers, (2) Once through sub- or supercritical boilers, (3) Nu-

clear reactors of the pressurized water and boiling water types.

This high quality eliminates the deposition of scale and corrosion products in the boiler and permits maintaining optimum heat transfer rates. The reduction of silica assures high turbine efficiency by minimizing turbine blade deposits. In nuclear reactors dissolved and suspended corrosion products must be eliminated to prevent the buildup of radioactivity. Finally, there are indications that chlorides and oxygen levels must be held at a minimum to prevent stress corrosion of austenitic steels.

By 1954 the authors were aware that rate of flow through a mixed-bed ion exchange column was not limited by the rate of reaction of the mixed ion exchange resins themselves. In fact, physical considerations such as head loss and related pumping cost, resin stability and degree of removal of suspended matter would control. This was demonstrated by the work of Moison and Caddell who reported that flow rates up to 100 gpm per square foot produced water with a conductivity of 0.5 micromhos or better. As a result the problems of a rapid cleanup of large quantities of radioactivity in the event of fuel element rupture in a nuclear reactor seemed possible of solution with a high flow rate ion exchange.

In early 1956, data accumulated over a period of many months were brought to the attention of a group committed to the construction of a large pressurized water nuclear reactor for the generation of electricity. The boiler was to be fabricated of stainless steel and a maximum concentration of 1.0 ppm chlorides for occasional operation and 0.1 ppm for continuous operation was prescribed for the boiler water. The possible need for condensate purification was apparent. Because of the large volumes of water involved, the most economical approach would indicate the use of high flow rate de-ionization. Field pilot plant studies were initiated and results are excellent.

J. G. Koopman and **E. M. Marselli** of Electric Energy, Inc., together with **James Jonakin** and **R. C. Ulmer,** Combustion Engineering, Inc., reported on the "Development and Use of a Probe for Studying Corrosion in Superheaters and Reheaters." Since the metal temperatures in today's 1050-F to 1200-F boilers will be approximately 150 F higher than these steam temperatures, metals must be selected with the necessary mechanical properties and be corrosion resistant to hot flue gases at metal temperatures up to 1350 F. If the coals burned in a plant operating at the higher steam temperature (1050 F or greater) are high in sulfur and alkalies which can form products having low melting temperatures, it is likely that deposits will form on the tubes and chemical corrosion result. This can occur at a gas temperature level in the order of 1800 F which is not normally associated with slag formation in the usual sense, such was the case at the Joppa station of Electric Energy, Inc., which burns a mixture of Southern Illinois and West Kentucky coals

The station has experienced difficulties with corrosion of superheater and reheater surfaces. Examination of tubes revealed that in some instance up to 50 per cent of the wall thickness in the reheat section of the boiler had been lost. The high cost of replacing tubes in addition to the loss of income because of increased down time of units for replacing tubes made it necessary that remedial measures be found. A search of the literature revealed that considerable work had been done on this problem but very little applicable data of a quantitative nature for corrosion resistance of alloys were available. To obtain these data and also to study methods for the reduction of corrosion this project sponsored by Electric Energy, Inc. and Combustion Engineering, Inc. was initiated.

Probe tests have been conducted at the Joppa Station of Electric Energy, Inc. The station consists of six boilers and turbines with the necessary auxiliary equipment. The hourly peak generating capacity is 1,050,000 kw. The yearly coal consumption is approximately 3,200,000 tons. The units were designed primarily for firing Southern Illinois and Western Kentucky bituminous coal.

Three alloys, Types T-11, T-22 and 321 stainless steel were tested under various conditions. Variables having the greatest effect on corrosion rate, namely, temperature of metal, time of exposure and composition of coal were studied. In addition the effect of gas temperature and coal fineness on deposit formation and related chemical corrosion were investigated.

The authors employed a figure to show overall results. This figure showed that metal wastage of 321 stainless steel as a function of temperature does not conform to the usual corrosion relationship, but is a complex function. It can be seen that the curve is "bell shaped" with the maximum wastage occurring at a temperature of approximately 1100 ±50 F with minimum wastage occurring below 900 F and above 1300 F.

The results obtained may appear to be contradictory to those obtained by other investigators. Eberle, et al., reported a negligible wastage of several stainless steels exposed a much longer period of time. But since their data was obtained at temperatures above 1290 F, very little wastage would be expected as shown by the low specimen weight loss for 1270 F and higher temperatures in the authors illustrated results.

Examination of the specimens after exposure indicated that the wastage shown in the figure occurred only under bonded deposits. To determine the extent of wastage of 321 stainless steel that could be expected if no deposits formed on the specimens a probe was located at the rear of the finishing reheater where the flue gas temperature was 1450 F and the particles of fly ash had frozen. No deposits formed on the specimens exposed at this location. These results indicate that wastage of Type 321 alloy is due to chemical corrosion as differentiated from gas-phase oxidation.

In similar vein the authors reported on the findings for the other alloys so tested.

Turbine Generators

Lloyd E. Smith, Tennessee Valley Authority, offered a paper on "Ultrasonic Testing of Large Steam-Turbine Parts." Ultrasonic testing of materials and equipment is an excellent method of nondestructive testing that is available to an electric utility for use at the location of the equipment. At present there are several other nondestructive testing methods which may be used in a specific application in conjunction with, or instead of, ultrasonic testing. Some of these other methods are

magnetized-particle crack detection; fluorescent and dye penetrants; X-ray; electrical conductance; and, of course, visual inspection.

The most logical application of ultrasonic testing is that of internal-flaw detection in metal parts that have only one surface available for application of the sensing unit, which is usually a vibrating crystal. Other applications involve the determination of thickness as a measure of whether erosion or a change of dimensions has occurred.

It must not be inferred, the author stated, that the ultrasonic testing of materials and parts is a very simple and easily learned operation. Some phases of inspection are so complex that the actual testing in the field should be done by the manufacturer of the machine. An example is the main rotor forgings on large steam-turbine generators that are tested in the various stages of manufacture. In this case the interpretation of results depends to a large extent on previous tests that are available to the manufacturer. Since the tests after installation are mainly the determination of whether very obscure changes are occurring over a number of years, it is better to have the tests performed by operators provided by the manufacturer.

Other tests can be made by the utility as field tests. Field tests are quite varied in their nature and may be tests of parts of the turbogenerator, as well as the accessories.

The author believes that ultrasonic testing has a definite place in the test program of an electric utility; and there are many tests that evidently are justified because of economy, as well as the assurance that a piece of equipment is in good condition and not likely to fail.

E. H. Miller and **B. M. Cain,** General Electric Co., discussed "Large Steam-Turbine Generators for the 1960's." During the next decade the nation's electric utility industry is expected to add 142 million kw of new generating capacity. To add this great amount of new generating capacity—equivalent to all the steam stations added since 1900—presents a challenge of tremendous magnitude.

A compact and basically simple family of steam turbines, in ratings from 100,000 to 500,000 kw, is available now. With modifications for higher steam conditions and improved steam paths, this family of turbines should cover adequately most applications of the next decade.

During the sixties maximum ratings up to 500,000 kw appear possible with 3600-rpm tandem-compound turbines; however, the maximum economic rating may be closer to 400,000 kw even with four rows of 29-in. last-stage buckets. For immediate application, two 3600-rpm, tandem-compound, four-flow turbines with 26-in. buckets are available. This design utilizes the opposed-flow, high-pressure reheat sections for compactness and simplicity with the full centerline supported casings, nozzle boxes and other improved design features of our modern line of units, so as to obtain the most desirable operating characteristics.

Beyond 300,000 kw, it has been found desirable to double-flow the reheat stages to limit the bucket loadings to conservative values. An extrapolation of present turbine-generator capability trends indicates that a unit of about 1,000,000 kw may be needed in the late sixties or early seventies. Certainly by that time there will be systems which will be large enough to install a steam turbine-generator of this rating without exceeding the traditional relationship of capacity of unit to size of system. Studies to date indicate a continued utility industry purse for large capacity units, and GE will continue its efforts to develop the most reliable and economical turbine designs at the largest feasible ratings.

J. K. Dixon and **G. W. Staats,** Allis-Chalmers Mfg. Co., joined in the paper "Progress in Steam Turbine and Generator Research and Development." The final test of turbine performance lies not in the laboratory but in the power station. For this reason a program is maintained, with the cooperation of the utilities, whereby each new design of turbine is subjected to an accurate performance test as soon as practicable after commercial operation has begun. The results of these tests, during the past several years, have shown that turbines are meeting or surpassing performance guarantees.

In addition to the development of blading, other elements of the steam path are receiving continuous attention. Determinations of losses in valves, strainers, exhaust hoods and diffusers are made with the use of low powered air sources. The results of some of these tests showed that it was possible to decrease the size of a turbine exhaust hood appreciably over previous designs and at the same time improve its aerodynamic performance.

In governing stage blading the most serious stresses are those in bending caused by the steam driving forces. As turbine inlet pressures become larger these forces increase proportionately. Here "tuning" is of no avail and blades must possess sufficient strength to withstand possible resonant vibratory stress. For many years governing stage blading for the highest pressure turbines has been attached to rotors by means of the familiar axial-entry fir-tree type root.

During 1958, development was conducted on a means of improving appreciably the strength of this type of fastening. This improvement has been achieved by brazing two impulse blades together to form a pair. A high temperature brazing procedure is used to join the blades at the inner diameter platform and at the shroud. Circumferential pins through shroud and platform add reinforcing.

Photoelastic studies showed that the double blade design has more than twice the strength of the former type of assembly. Strain gage tests of metal models confirmed this fact. Physical tests of brazed blades showed that, with proper control, blade material properties suffered no impairment whatever. Fatigue tests showed that the brazed joint possessed adequate strength. Brazed pairs of governing stage blades are now in service in a number of our latest turbines.

Other phases of turbine and generator design were discussed and the more outstanding advances reported.

H. R. Reese, Westinghouse Electric Corp., presented "Advance Developments in Component Design for Large Steam Turbines." According to the author, fundamental concepts of high pressure and temperature designs were placed in operation over ten years ago. Many years of operation are required before a design is proved

satisfactory. The author's company believes that their design philosophy, which includes separate nozzle chambers, separate stop-throttle valves, separate steam chests and effective use of mass flow cooling to minimize the effect of thermal stresses, has proved not only satisfactory but necessary, based on past operating experience.

At best this summary of effort is an estimate. The author's company believes it is important that we recognize future power demands with a well-planned program. Such a program would include interchangeability of basic elements among the turbine arrangements, as well as, a more uniform heat balance arrangement that would cover average conditions. A more uniform basic plant design practice would be very helpful in the overall program.

Pre-engineered machine components can be assembled in almost any combination for 3600 rpm turbines and for inlet steam conditions up to 2400 psig 1050 F with reheat up to 1050 F.

For ratings of 600 to 750 Mw it may become desirable to consider steam conditions of 3500 psig 1050 F. The cross compound sextuple flow machine consists of two triple exhaust machines, the high pressure shaft headed by a very high pressure element (3500 psig 1050 F) the intermediate pressure shaft headed by the same basic intermediate pressure element mentioned previously.

The cross compound octuple flow arrangement gives rise to consideration of even higher inlet steam conditions. Perhaps pressures of 5000–6000 psig and temperatures up to 1200 F would prove economical. This machine consists of two tandem compound quadruple flow machines with the high pressure element on one shaft replaced with a super pressure element. The previous two arrangements will support ratings up to 1000 kw should they prove economical.

The main point of the preceding discussion is that combinations of 3600 rpm turbines may be made up from tandem compound double flow, triple flow and quadruple flow machines. Increased ratings are produced by adding high pressure and temperature front ends to a multiplicity of elements that go to make up the three basic machine arrangements.

Operating Experiences

T. T. Frankenberg, A. G. Lloyd and **E. B. Morris,** American Electric Power Service Corp., combined to present a report on "The Second Year of Operating Experience with the Philo Supercritical-Pressure Unit." Some overall comparisons of the first and second year's operation were made.

A table was presented which showed increases of 22 per cent in average net generation to a present level of 95 Mw for this operating period over that reported last year. To place these two periods on a reasonably similar basis, the omission of a four-month outage for inspection and corrective work, during which no operation was planned, was felt justified.

A large portion of the marked increase in both average load and availability must be credited to improved reliability of the feed pumps. Work is still continuing toward optimum seal design, but forced outages of these pumps have been practically eliminated. With few exceptions the unit, when available, operated at full output.

Early in 1958 it was discovered, through a routine check of turbine thrust loading, that this turbine had developed an abnormally high thrust compared to the expected design value. Plans were made for an extended outage to inspect the turbine and to perform required modification of other equipment. On May 27, when turbine thrust had increased to the agreed-upon limit, the unit was removed from service. The findings and corrective measures involved during this outage were described in detail; the major items included:

a. Discovery of copper deposit in the high pressure turbine.
b. Modification of the high pressure turbine to reduce the thrust level to obtain additional margin for contingencies.
c. Elimination of the high pressure turbine rotor-cooling, not needed for the austenitic rotor.
d. Discovery of cracking at attachment welds in stainless-steel steam piping.
e. Modification of turbine stop-valve seats.
f. Steam generator modifications to reduce slagging and fly ash difficulties.
g. Replacement of welds between dissimilar metals in the steam generator.

Operation since returning the unit to service has been very satisfactory. Turbine thrust has been monitored closely and an extensive test program has been in progress for determining source and mechanism of the copper deposition. Details of operation following the outage were discussed later.

W. O. Barnett, U. S. Steel Co., opened his paper, "Boiler Control System for Multi-Fuel Firing," with the declaration that one of the many problems existing in industry today is the efficient utilization of so called waste fuel. A million Btu of heat energy in Mr. Bennett's opinion is worth exactly the same amount of money regardless of its source.

At the Fairless Works with which Mr. Barnett is familiar three fuels are available: blast furnace gas, coke oven gas and residual fuel oil. In using these three fuels in the Fairless boilers the problem is to be able to interchange fuels as they are available on a Btu basis and supply the proper amount of air.

The most unusual feature of the control system, in Mr. Barnett's opinion, is the fuel flow sequence. The fuel preference is blast furnace gas, then coke oven gas and finally residual fuel oil.

It was necessary to meter both the fuel and the air to each burner to obtain the correct mixture. A large air duct was run from each side of the air heater outlet along the sides of the boiler and around to the front, or burner side of the boiler. This divided into sections so that each section became a separate air duct for one individual burner. Each section has a venturi provided with meter taps to accurately meter the air to each burner. However, due to the size of the blast furnace gas burners and the fact that three burners are installed, the center burner has two half-size air ducts, two separate combustion air control valves and a meter on each air duct. The signal for air to this center burner is divided and each air control valve drive receives one-half of the signal. The meter signals are then totalized to balance the total fuel signal to the center burner.

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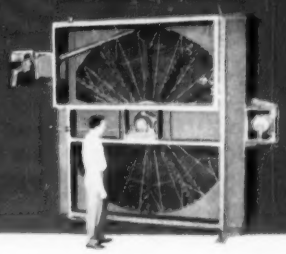

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THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part IX

QUESTION

In one of your articles you suggested that if a boiler feed pump has reasonably ample internal clearances and a heavy enough shaft to hold the deflection to a minimum it is safer to keep the pump running under flashing conditions rather than to shut it down. We have experienced several cases that would tend to support your recommendations. In this connection, we would like to ask you two questions:

(1) Do you feel that pumps can be operated during flashing conditions for extended periods or only during the short period time normally required to restore conditions to normal? In other words, is there any time limit?

(2) In the case of seizure at full speed, would not the damage to the pump be more severe than if the pump seized while coming to rest? It seems that, especially in the case of the motor driver, this would be true.

ANSWER

At the time I first wrote about the wisdom of letting a pump which has flashed continue running, provided the pump did not depend on water lubrication at the wearing rings or internal bushings for shaft support, I had only three properly authenticated cases to support my theory.[1] Of course, I had reached this conclusion as much from a theoretical analysis of the events which accompany a seizure after shutting a pump down as from field experience. Nevertheless, it has been gratifying to collect several more documented cases which have reinforced my conclusions on this particular operating practice. In one particular case, it has been reported to me that boiler feed pumps have operated under flashing conditions for as long as 10 minutes during certain emergencies. Tests run on the pumps afterward indicated no noticeable damage or loss in capacity.

However, I find it difficult to answer your first question in a truly "quantitative" manner, mainly because I still feel that insufficient evidence is yet available on this score. I find it almost impossible for a set of conditions to arise which would permit us to establish time-limits—if such do exist. Nor can I realistically expect a utility to voluntarily perform such an experiment, considering the potential risks involved and the stakes of the game.

On the other hand, looking at it from a logical point of view, if a pump can run flashing without seizing for 10 minutes, why can we not expect it to run safely for 60 minutes? And if for 60 minutes, why not for 24 hours?

It probably could be done, but could it be readily proved? And if it can be done, is it an important achievement? Frankly speaking, is a time-limit a necessary thing to know? I think not. I prefer to take the position that once a pump has flashed, it should be kept running (providing it meets the design criteria I have mentioned) and all efforts should be directed towards restoring adequate suction conditions in as short a time interval as possible. After order has been restored, try and find out the following three things:

(*a*) How long has the pump run under flashing conditions?

(*b*) Is the pump still sound or has some damage occurred?

(*c*) What caused the flashing, so that protection against a recurrence can be developed if at all possible.

As to the possible damage to a pump and its driver from a seizure at full speed, there is no question but that it would be much more severe than were the seizure to occur as the pump was coasting down to rest. I personally know of only one case of "full speed seizure," but it was of catastrophic proportions. I should add, however, that its cause was not flashing of the feedwater but rather mechanical damage to some of the impellers, followed by extreme vibration and finally by overheating of the shaft at one point through rubbing contact, and breaking of the shaft. In the case in question, a hydraulic coupling was interposed between the pump and its motor driver so that the latter suffered no damage.

Essentially, the potential damage of a seizure at full speed is very similar to that suffered by a steam turbine which starts throwing blades and which, if not stopped in

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[1] "How Do You Operate Your Boiler Feed Pumps?," by I. J. Karassik, *Power Engineering*, March 1957, Worthington reprint RP-923.

time, will be a total loss. At the same time, I repeat that I have no direct knowledge of a pump seizure at full speed under flashing conditions. Thus, a pump which goes into severe vibration because of mechanical causes should be stopped before complete disintegration occurs, while a flashing pump which manages to operate as a centrifugal steam compressor is best left running.

This reasoning is based on the following considerations: it is practically a certainty that a pump which is brought to rest while steam-bound because of inadequate suction conditions will seize and serious damage will take place. On the other hand, the chances of surviving unscathed if kept running are very high. It is therefore sound operating practice to choose that course of action which has the greatest odds in favor of success, despite the risk of greater damage, should events depart from the usual.

QUESTION

We are investigating the use of measured temperature rise across boiler feed pumps as a means of controlling boiler feed pump recirculation. Do you know of any installations equipped with this type of recirculation control and what is your opinion of this type of control? Incidentally, should the recirculation bypass be returned to the heater at the pump suction or to the suction line itself?

ANSWER

The first reaction to the use of measured temperature rise across a boiler feed pump as an impulse to operate the recirculation bypass control valve is a favorable one. One of the greatest advantages is that such a control becomes most accurate in the range of its greatest need, that is at the greatest temperature differences between the suction and discharge. On the other hand, the flowmeter control which is more generally used is least sensitive at the light flows when the temperature rise requires operation of the control. Another advantage of the temperature rise control is that it would not be necessary to calibrate it for every single pump to which it is applied, since a recommended maximum rise in temperature would be selected and would then become the impulse which would open the recirculation valve.

Unfortunately however, temperature rise controls would have a very appreciable time lag in registering a temperature rise such that the recirculation bypass must be opened. This time lag could lead to dangerous operation of the boiler feed pump at excessively reduced flows. This has been the major reason for the fact that flowmeter control has always been preferred to temperature rise control as a means for actuating the recirculation bypass valves.

I have no direct knowledge of any boiler feed pump installations embodying temperature rise controls, but some reader may possibly be familiar with such an installation. In such a case, I would be very pleased to receive any information he may be able to furnish to me. I do remember a descaling pump installation made some ten or fifteen years ago which included temperature rise controls. Because the pumps were handling cold water and had a very ample suction pressure, it had been considered less dangerous to use a control with the inherent time lag involved.

The recirculation bypass flow should *always* be returned to the direct contact heater at the pump suction (or to the condenser in the case of closed feedwater cycles), rather than to the pump suction. Otherwise, a cumulative temperature rise would take place and very shortly the permissible temperature rise would be exceeded. In other

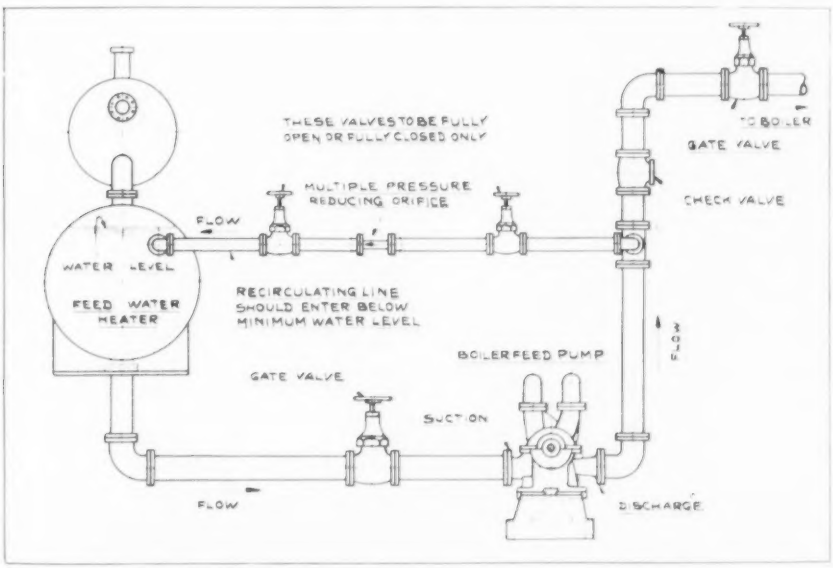

Fig. 1—Boiler feed pump bypass piping arrangement

words, the bypass should return to some place in the cycle where the heat picked up by the water during its passage through the pump can be dissipated. Generally, an arrangement such as shown on Fig. 1 is used. Two valves are installed, one on each side of the orifice which controls the flow through the bypass. One of these valves is locked open and is only intended to isolate the orifice during inspection or renewal. The second valve is the control valve and is opened whenever the flow through the pump falls to a value such as to cause an excessive temperature rise. This valve can be operated either manually or automatically, preferably the latter.

National Coal Policy Conference

PHILIP SPORN, president of the American Electric Power Company, one of the principal speakers at a Congressional Dinner in Washington (April 27, 1959) of the National Coal Policy Conference, called for a Congressional study leading to the establishment of a national fuels policy for the nation.

Mr. Sporn is a member of the executive committee of the NCPC, which is composed of coal producers, the United Mine Workers of America, some 30 leading coal carrying railroads, utilities and suppliers to the coal industry. The Conference was formed early this year to bolster the economic strength of the American coal industry and to help it maintain its productive capacity at a level capable of meeting the anticipated great demands on it within the next few years, as well as to respond to any national emergency in which coal would have to provide the major new source of energy to the nation's power plants and factories.

Other speakers at the meeting were John L. Lewis, president of the United Mine Workers; Howard E. Simpson, president of the Baltimore and Ohio Railroad Company; and George H. Love, chairman of the Consolidation Coal Company of Pittsburgh.

Mr. Sporn predicted that energy demands of the United States would increase by two and one-half times by the year 2000, and that coal would have to supply a substantial part of the fuel for such expanded output. Total annual demand for coal by then will be around 900 million tons, he estimated, or more than double the 1958 output.

He warned, however, that if the coal industry is to be able to supply one-third of the country's energy requirements 40 years from now it must solve its current problems and "survive what currently is a near crisis in its economic conditions.

"If coal is to successfully play its indispensable role in the future—a role without which the welfare and even the defense of this country cannot be assured—then coal must have markets, earnings and employment for its skilled work force in the present—right now," Mr. Sporn declared.

He pointed out that the question of coal's economic strength was of serious concern not only to the coal industry, itself, as well as the utilities so dependent on it, but also to the railroads which derive a substantial portion of their revenue from hauling coal, and to the "very well-being, strength and even survival of the United States.

"The coal industry has had a great history," Mr. Sporn declared. "It has provided the very foundations of the industrial expansion and development in all of the Western World, starting with the Industrial Revolution some 200 years ago. Its first use was as a source of heat energy converted into mechanical energy; later as a major component in steelmaking. If the last 50 years have been the Age of Steel, they have been even more so the Age of Fuel-Generated Energy, and until quite recently this has meant primarily the Age of Coal.

"Although oil and natural gas have now been under development for about 100 years in this country, their growth to a position of primacy in the energy picture of this country has been relatively slow and gradual. Natural gas, particularly, made no significant impression on the energy supply of the country until the last decade and a half.

"In 1920 coal, both bituminous and anthracite, supplied over 78 per cent of the energy consumed in this country, and as recently as 1947, when the production of bituminous coal reached its historic all-time peak of 630 million tons, it still provided about 50 per cent of this country's energy supply. But since that date there has been a rapid change in coal's position, and coal production has now declined to the point where, in 1958, it supplied less than 25 per cent of the country's energy, while oil and gas supplied over 70 per cent. Coal production has fallen from the record levels of 1947 by over 200 million tons, or about one-third.

"This, of course, has confronted both the management and labor segments of the coal industry with many very difficult adjustments. Some people have been prepared to write off the coal industry as a major factor in our economy, but this certainly is not true of those who are knowledgeable or who have given serious thought to our energy problems. It definitely is not true of the coal industry itself, which in the postwar period has made substantial strides in technology that have rapidly increased efficiencies and productivity.

"And yet the coal industry is in difficulties. These difficulties have resulted from several important developments. In railroad transportation, the rapid change to the diesel locomotive since 1947 has resulted in almost complete loss to the coal industry of a market that at its peak was close to 150 million tons per year. The extensions of gas pipelines throughout the country in that same period have materially decreased coal's position in the home-heating market. The competition of imported oil, particularly residual oil, in the Eastern seaboard has made significant inroads on coal's markets both in utility and in industrial fields. The combined effect of these last two attritions has been a loss close to that of the railroad market.

"Thus, there now remain only two major growing markets for coal—the metallurgical and the electric power—and of these two, the more rapidly growing by far is the electric power market. Since 1947 the increased tonnage consumed by the utility industry has absorbed about 70 per cent of the lost railroad tonnage."

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REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N.Y.

Elementary Matrix Algebra

By Franz E. Hohn

305 pages, 6" × 9 in. $ 10

The handling of numbers in blocks or matrices has always been a powerful mathematical tool. With the current interest in computers this tool has an increased appeal. We review it here for those in the industry who feel they could profit from an up to date compilation of those aspects of matrix algebra and determinant theory. Actually the book is a development from a course given at the University of Illinois to students of diverse interests whose objective is to gain a certain mastery in the application of matrices to the field of their interests. The topics are separated into distinct chapters to make the book more useful as a reference volume.

Conference on Extremely High Temperatures

Edited by Heinz Fischer and Lawrence C. Mansur

258 pages, 8½ × 11 in., $9.75

In March of 1958 the Electronic Research Directorate of the Air Force Cambridge Research Center sponsored a conference on the title subject of this book. The conference papers have been compiled here. Emphasis is on the high temperatures as they affect and relate to the propulsion field. The basic physics of these high temperature effects is, however, discussed in the explanations by those submitting the various papers. It is in this area of basic physics that the more research minded of the conventional power field will find this book of value.

Industrial Water and Industrial Waste Water

ASTM Special Technical Publication No. 207, American Society for Testing Materials, 52 pages, 6 × 9 in., $2

Several aspects of the problem of industrial water supply and wash disposal were presented at a symposium before the Second Pacific Area National Meeting of the ASTM in Los Angeles, under the auspices of the society's Committee D-19 on Industrial Water. Among the papers presented and published were: "There is a Vital Number (Introduction)," "D-19, The First Quarter Century," "Industrial Waste Problems in Southern California," "Water Pollution Control in the Los Angeles Area," "Sea Water Purification," and "The Use of Organic Flocculants and Flocculating Aids in the Treatment of Industrial Waste Water."

Unit Operations of Chemical Engineering

By Warren L. McCabe and Julian C. Smith

945 pages, 9 × 6-in., $10.50

This impressive volume is published on the theory that chemical engineering is based on two facts: (1) each process may be broken down into a series of steps or operations which appear in process after process, (2) individual operations have common techniques and are dependent upon the same scientific principles. By studying systematically these operations themselves—operations which clearly cross industry and process lines—the treatment of all processes is unified and simplified. The authors then single out basic operations for their text. Fluid mechanics, flow of heat and mass transfer are thoroughly explored for the scientific foundation and theory they bring to bear on the subject matter.

Handbook of Air Conditioning, Heating and Ventilating

By Clifford Strock

1112 pages, 7¾ × 10¾ in., $15

Thoughtful selection and preparation of useful and authoritative engineering data for air conditioning, heating and ventilating by one of the industry's leading editors have produced this comprehensive workbook for engineers and students in those fields. The publication features condensations of material by a list of authorities plus much new data never before published.

A few of the firsts in this big book are: Complete tables of heat losses from insulated pipe; heat losses by transmission and infiltration through every standard type and size of window; new data on steam flow in pipes, the most extensive collection of degree-day and climatic maps ever published for this field including design temperatures, sun, snow, ground water and seasonal data.

Other notably complete data include psychrometric tables and charts for a wide range of temperatures and pressures; tables of heat losses from buildings; design of high velocity and dual duct systems; combustion data for all fuels; hourly and seasonal solar data specifically for engineers; design data for all standard pipe and tube including plastic; a full 173-page section of mathematical tables, conversion factors and drafting symbols.

Thermodynamics of Heat-Power Systems

By F. W. Hutchinson

490 pages, 6 × 9 in., $8.50

The author in his preface points out that a new book in an old field needs self justification. In his opinion thermodynamics and its teaching have suffered from a stereotyped treatment and in his twenty years of handling the subject a different pattern had evolved. This pattern is to conceive of thermodynamics as the study of energy particularly in its thermal and mechanical manifestation. Such a pattern brings to the subject a continuity which the author depicts as a seven linked chain.

The text offered to support this teaching approach has been made purposely qualitative for the student's reading acceptance. The quantitative or problem-type development of the subject has been left largely for the classroom. The book then becomes a descriptive one of the fundamentals at issue.

Heat and Thermodynamics

By Mark W. Zemansky

484 pages, 6 × 9 in., $7.50

Although admittedly a textbook for the intermediate student about to enter a field of specialization in engineering, chemistry or physics the author has not presumed upon an especially strong mathematical background. Mathematical theorems beyond the elementary calculus are derived and explained in the body of the text as their need arises. Very few back references to previous equations are made and where repetition is in order the author repeats a pertinent equation. The basic fundamentals including such items as heat, temperature, work, internal energy, reversibility and entropy absorb the first ten chapters.

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion Ltd., London, W.C. 1)

Fuels: Sources, Properties and Preparation

The Influence of Volatile Content on Sulfur Removal From Coal During Coking. D. Mirew and I. Zlateva. *Brennst Chemie* 1958, **39** (Dec.) 366–8.

Investigations into the relationship between volatile content and sulfur removal during coking have shown that the transfer of sulfur to the distillation products increases with increasing V. M. content. Coking in an ammonia atmosphere increases sulfur removal. In coking coals, the removal of the sulfur is made more difficult by the fusion of the coal. In high volatile (young) coals a large amount of sulfur can be removed pyrochemically in a hydrogen or hydrogen containing gas atmosphere.

Progress Review No. 46. Coal Carbonisation—Coke Oven Practice. C. W. Wood. *J. Inst. Fuel* 1958, **31** (Dec.) 541–7.

The review deals with (1) Coking coals; (2) coal handling, preparation and blending; (3) coke ovens; (4) oven design; (5) oven doors; (6) coke handling; (7) refractories; (8) oven machines; (9) safety devices; (10) by-products; (11) sulfur removal; (12) effluents.

Pneumatic Transport of Pulverized Coal. J. Commissaire. *Institut Français des Combustibles et de l'Énergie (Solid Fuel and Pulverised Fuel Conference 1957, Paper No. 4.03).*

The present state of knowledge in relation to the transport of pulverized coal by means of air is discussed with reference to the nature of the problem, the case of straight horizontal pipes and pipes with elbows, pressure drop in pulverized coal pipelines, classification of pulverized coal, mills, combustion of lean coal, difficulties encountered in transporting pulverized coal, and sampling.

From *C.E.G.B. Digest* 1958, **10** (Dec. 20) 3457.

Steel Plate Conveyors on Steep Gradients. L. M. Reid. *Iron & Coal Tr. Rev.* 1958, **177** (Dec. 19) 1457–61.

A steel plate conveyor of German design is described which can be fitted with multiple drives to transport material, especially coals, over great length and steep inclines. A special feature is the device for stopping the conveyor when a chain breaks to prevent damage to the system.

Design Considerations for Pneumatic Coal Handling System. W. Gruca. *Combustion* 1958, **30** (Nov.) 57–61.

The coal received by car is transported by belt conveyor from the track hopper to the crusher where it is reduced to $^3/_4$ in. and thence passed to a small surge hopper from which a rotary feeder moves it into the air stream (4–6 psi). The overall length of the pipeline is 469 ft with 393 ft horizontal and 76 ft vertical travel. In the boiler house, branches provided with diverter valves take the coal-air stream to the various hoppers which are vented to a common bag filter. The plant has a capacity of 150 t/day with a consumption of 0.488 lb of air per 1 lb of coal and a power consumption of 2–3.2 kwhr per ton coal. Difficulties experienced and remedial measures applied concerning the transport of wet and frozen coal, wear in the rotary feeder, pipeline, diverter valves and bag filter are described. Because of the heavy degradation of the coal, the system is only applicable to pulverized coal firing. Fire hazards have not been experienced and the system has operated reliably for over 4 years, during which 81,000 tons of coal were delivered to the hoppers.

Macerals. J. K. Brown. *B.C.U.R.A. Monthly Bull.*, 1959, **23** (Jan.) 1–17.

A detailed review is presented of: 1. Nature of macerals (microscopic elementary constituents of coal); 2. Their separation; 3. Basic physical and chemical properties; 4. Chemical structure; 5. Carbonization behavior; 6. Coking properties.

Prediction of Fouling Tendencies of Coals. K. Wickert. *Energie* 1959, **11** (Jan.) 18–9 (In German).

A brief supplement to the author's article of the same title (abstract 3712, 1958) containing a few more data. The boiler fouled completely in a few days if the coals contained 0.09–0.16 weight per cent water-soluble Na_2O in the dry coal and 1.8–2.06 weight per cent S, but had an average availability if the water soluble Na_2O did not exceed 0.035 weight per cent and the S content did not exceed 1.4 weight per cent. Fouling increased sharply when the coals contained 0.046 weight per cent water-soluble Na_2O, 0.023 weight per cent water-soluble K_2O and 1.66 weight per cent S.

Underground Gasification Tests to End. Anon. *Iron & Coal Tr. Rev.* 1959, **178** (Jan. 30) 241.

The underground gasification tests at Newman Spinney are to be ended early in the Summer of 1959, as the results achieved so far do not warrant further expenditure. It appears that the thin seams are not suitable for gasification by either the method developed by the N.C.B. or the modified Russian method.

Natural Gas Comes by Sea. Anon. *Engineering* 1959, **187** (Feb. 20) 232–3.

On February 21, 1959, the first tanker carrying liquified methane from the Gulf of Mexico to Gt. Britain arrived in the Thames Estuary where it will discharge its content into five specially built storage tanks. The economics of the scheme are discussed.

The Pneumatic Conveying of Spheres through Straight Pipes. J. A. Hitchcock and C. Jones. *Brit. J. Appl. Phys* 1958, **9** (June) 218–22.

A technique for the study of pneumatically conveyed solids is described and two equations, established experimentally, are given for the pressure gradient and solid velocity along a pipe when non-adhesive spherical particles are being conveyed with little or no acceleration by an air stream through the pipe. Results of tests are given.

Ash Handling: A Modern Approach. Anon. *Power* 1959, **103** (Feb.) 61–3.

The furnace and fly ash handling system at O. H. Hutchings station are described. The furnace ash is collected in a hopper and transported intermittently by hydraulic means to an ash sump. The fly ash from the boiler and dust collector hoppers is removed by vacuum, mixed with water and then added to the ash sluicing system. The operation of both systems is controlled by an automatic sequence regulator.

State Line Improves on Fly Ash Handling. L. J. Luckenbach. *Pwr Engng* 1959, **63** (Feb.) 75–6.

The pneumatic conveying system at the State Line station is described. The hot fly ash from the precipitators is fluidized and moved at a slightly downward inclined angle to a central transfer point which delivers the fly ash to a surge hopper. Pumps underneath this hopper discharge the ash to a mixing chamber where compressed air (30 psi) entrains it and transport is through a pipe line to storage, where the fly ash is either filled into bags or stored for bulk delivery. The whole plant operates automatically and is controlled from the central control room. This plant arrangement portrays the thought others are giving to this problem.

Heat: Cycles and Transmission

Gas Flow Across Banks of Tubes. J. M. Miller and G. F. S. Reising. *Engineering* 1958, **186** (Dec. 5) 737–40.

Investigations carried out by Babcock & Wilcox Ltd. into heat transfer and pressure drop in tube banks by means of several test rigs are described. Results obtained have been given previously.

Investigation into the Critical Velocity of Stripping the Film from the Wall of a Pipeline. N. A. Mozharov. *Teploenergetika* 1959, **6** (Feb.) 50–3 (In Russian).

The critical velocity of flow of saturated steam at which the film is stripped from the wall of a pipe has been experimentally investigated; the results are presented in graphs.

How To Save Money on Boiler Installations and Maintenance

New Thermastic Super By J. H. France chalks up real Savings. It's a paste-like mastic.

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Advances in Boiling Heat Transfer. Anon. *Brit. Chem. Engng.* 1959, **4** (Mar.) 164, 166.

An annotated review of recent papers on this subject.

Simultaneous Heat and Mass Transfer in Cooling Towers. Pt. I. W. J. Thomas and P. Houston. *Brit. Chem. Engng.* 1959, **4** (Mar.) 160–3.

The analysis of simultaneous heat and mass transfer is presented and the apparatus and experiments carried out to verify the theory are described. The results are tabulated.

Steam Generation and Power Production

International Steam Table Conference in Moscow. E. Schmidt. *BWK* 1958, **10** (Dec.) 553–6 (in German).

The conference held on July 21 and 22, 1958, discussed recent progress and problems in setting up new steam tables. A new steam table for a 1000 atm and 1000 C by Professor Voukalovitch has recently been published in English, French, German and Russian. Work regarding viscosity and heat conductivity and obtaining agreement between the thermodynamic and international temperature scale is to be reported at the next conference in Munich in 1960.

Proposal for the Establishment of International Steam Tables. H. Hauser. *BWK* 1958, **10** (Dec.) 557–60.

A new method based on stepwise approximation for obtaining consistent values of enthalpy and specific volume is described.

Prediction of Critical Pressures for the Two-Phase Flow of Saturated Water in Pipes. D. O. Stuart and G. Murphy. *ASME Preprint* No. 58 A-112 1958 (Dec.) 8 pp.

A mathematical and experimental study of the problem is presented. The paper requires close reading to establish the author's background for conclusion.

Relationships Between Limit Values of Specific Heat Release Rate and Water Quality in Evaporating Tubes of Oil and Pulverised Coal Fired Boilers. P. Pracht. *Energie* 1958, **10** (Nov.) 461–6 (in German).

Laboratory experiments and investigations on power station boilers have shown the connection between rate of water circulation, specific heat release rate and feedwater quality, and led to the establishment of limit values which when exceeded may lead to tube failure due to scale formation and overheating. The influence of pressure is also discussed. The different conditions for forced and natural circulation boilers are set out.

The Experimental Investigation of Specific Volume of Water and Water Vapor in the Region of High Temperatures. V. A. Kirillin and S. A. Oulibin. *Teploenergetika* 1959, **6** (Jan.) 62–5 (In Russian).

New experimental values of specific volumes of water and water vapor are presented for the range 600–650 C and 70–500 ata.

Equations for Determining Steam Purity, Extraction of Minerals from the Boiler Cycle and the Requirements of Feedwater Supplied to Universal Pressure Boilers Arranged with Scrubbing Devices. I. I. Koshelev. *Teploenergetika* 1959, **6** (Jan.) 14–22 (In Russian).

The operating conditions and effectiveness of scrubbing devices in once-through boilers are considered. Equations are developed for predetermining steam purity.

Steam Generators

Steam Generator Design Problems. H. v. Benten. *VDI Z.* 1958, **100** (Dec. 11) 1671–3 (in German).

The following are discussed: (1) The arrangement of heating surfaces to obtain maximum heat transfer with minimum costs; (2) uniformity of superheated and reheated steam temperatures by spray desuperheating, heat exchange between superheated steam and steam to be reheated, and the use of a spirally wound radiant superheater with 64 threads; (3) transport and construction of a completely shop-fabricated tube-platen superheater of austenitic steel with a new kind of joint between ferritic and austenitic steels; (4) a shop-fabricated lower part of a slagging furnace of hyperboloid shape with straight, though inclined, tangent tubes.

Performance Tests of a Vertical Steam Generator for Nuclear Plants. R. L. Colt and C. C. Peake. *Mech. Engng.* 1958, **80** (Dec.) 56–60.

The design and performance of a vertical steam generator producing saturated steam at 320 psi are described. Steady state and transient performance, moisture carryover and 3 sets of controls were tested. Operation was very similar to that of conventional boilers and difficulties were not experienced.

Steam Generators in Heat-Power Stations. R. Cleve. *Energie* 1958, **10** (Nov.) 453–7 (in German).

The various designs and sizes of boilers supplied by Borsig for outputs of 4–210 t/hr are described. They include horizontal and vertical shell and water tube boilers fired with

wood, coal (traveling grate and p.f.) and oil.

Liquid and Gaseous Fuel Firing

Problems Encountered with the Use of High Sulphur Content Fuel Oils at Marchwood Generating Station and Experience with Chemical Additives. T. J. Wilkinson and D. G. Clarke. *J. Inst. Fuel* 1959, **32** (Feb.) 61–72.

Deposit formation, clogging and corrosion of superheaters, economizers, air heaters, grit arresters, precipitator concrete and insulators, ducting and stack due to the firing of oil containing an average of 4.2 per cent S and the various methods tried out to reduce the trouble are described in detail. In addition to modifications to the boilers the following additives were used over longer or shorter periods: ammonia, pyridine, proprietory powder additives "A" and "B," dolomite, magnesium oxide, magnesium carbonate and carbon monoxide; of these, ammonia, additive "A," dolomite and magnesium carbonate were successful to a certain extent. At present ammonia is used. Further experiments with dolomite and magnesium carbonate will be made. It is concluded that it is essential to keep the metal temperature of the cast iron and mild steel tubes of the air heater as high as possible by recirculation to prevent corrosion and clogging.

Direct Heating of Fuel Oil. Anon. *Engineering* 1959, **187** (Feb.) 191.

Direct fired oil heaters are used for heating the oil in the tanks and the pipelines to the burners. The system has an overall efficiency of 80 per cent compared with 50–60 per cent of systems using steam tracing.

Water-Side Corrosion And Water Treatment

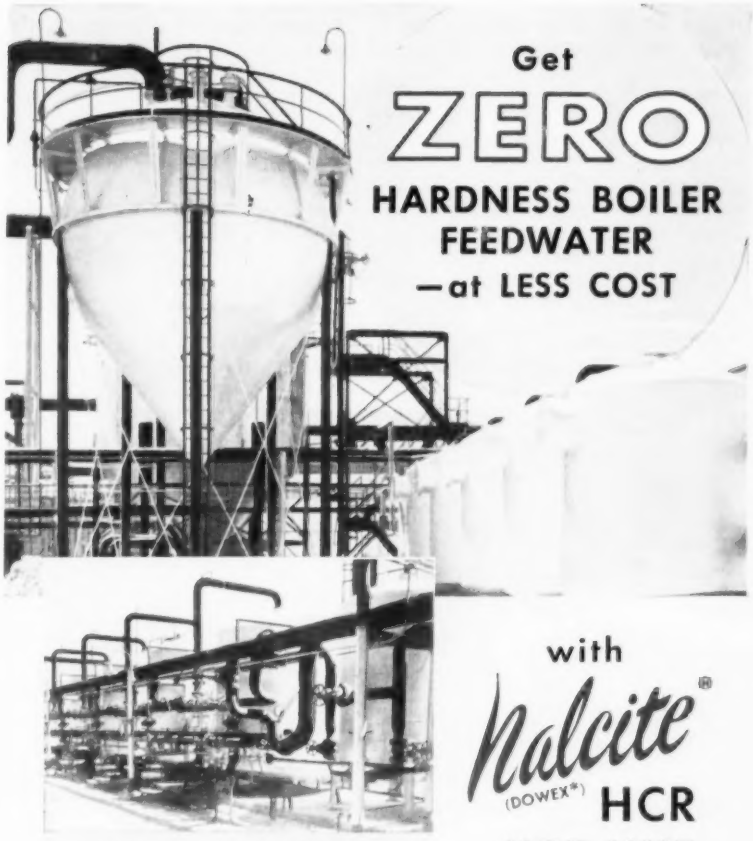
Water Treatment—Part I. R. H. Marks. *Power* 1958, **102** (Dec.) 73–104.

The first part of the special report deals with water impurities, analysis, chemicals used, lime-soda softeners, ion exchange systems and evaporators.

Limitations on Chemical Means of Controlling Corrosion in Boilers. D. E. Noll. *Corrosion* 1958, **14** (Nov.) 61–4.

The various forms of water-side corrosion in boilers, their causes and remedial measures are discussed. It is pointed out that some forms of corrosion cannot be alleviated by chemical means and that in these cases acid cleaning of the boiler is necessary.

Complete Chemical Demineralization. A. Schor. *Energie* 1958, **10**



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(Nov.) 467–71 (in German).

The chemical reactions taking place in cation and anion exchangers are presented and examples of modern complete demineralization plants given. Values obtained from actual plants show that the total residual salt content was 0.025 ppm and the total residual silica content 0.02 ppm. This is contrasted with a residual salt content of 1 ppm, the optimum obtainable in an evaporator.

Three Years' Field Testing Proves New Scale-Removal Method. J. J. Alexander. *Pwr. Engng.* 1958, **62** (Nov.) 61–3.

The application of a chelating agent "Versene 100" and "Versene Acid" to the water-side cleaning of boiler drums and tubes is described. The chemical was added to the boiler water after the pressure had been reduced to 150 psi and natural circulation was induced by intermittent firing. The process required about 18 hrs. Inspection showed 80 to 90 per cent cleanliness of the tubes and further cleaning took place after full operation had been resumed. The new method appears to be considerably more economical than other methods of boiler cleaning.

What can new Morton LEVETROL do for you? Read all about it on page 77.

Treated Boiler Water. Anon. *Engineering* 1959, **187** (Feb. 20) 247.

Abstracts are given of two papers presented to the Inst. Chem. Engrs: 1. Feed Water and Boiler Water Standards in the Central Electricity Generating Board by R. L. L. Rees and F. J. R. Taylor; 2. The Treatment of Water for Industrial High Pressure Boiler Plant by J. Arthurs, J. A. Robins and T. B. Whitefoot. The values laid down by the CEGB and ICI are compared.

How Yarmouth Gets Fully Automatic Water Treatment. A. G. Zeigler. *Pwr. Engng.* 1959, **63** (Jan.) 75–6.

A completely automatic boiler feedwater treatment and regeneration installation is described, consisting of a dual-bed demineralizer, dual cation and anion tanks, single caustic and acid regenerant tanks and a waste neutralizing system. The cation unit is regenerated after a predetermined volume of water has passed, the anion exchanger when the conductivity indicator-controller senses a deterioration of the quality of the effluent water.

About Water Conditions of the Soviet Once-Through Type Boilers of Ramsin's System. N. G. Patzoukov, J. M. Kostrikin and J. O. Novi. *Teploenergetika* 1959, **6** (Jan.) 22–7 (In Russian).

The principal conclusions drawn from investigations into water conditions for these boilers are presented.

Behavior of Calcium Hydroxide and Chloride in the Circuit of Uniflow Boilers. U. F. Samoilov and O. K. Smirnov. *Teploenergetika* 1959, **6** (Feb.) 53–7 (In Russian).

The behavior of $Ca(OH)_2$ and $CaCl_2$ in the steam-water circuit of forced flow boilers has been studied and it is suggested that physico-chemical transmutations occur at supercritical pressures and very high temperatures.

Cyclohexylamine in Water Treatment. W. K. Ashcroft and P. N. Heron. *Engng. Boil. Ho. Rev.* 1959, **74** (Feb.) 51–3.

The properties of cyclohexylamine, set out in full, are considered specially useful for protecting condensate lines against corrosion. Reports from the literature are quoted to show that this agent has given satisfactory service in the power stations in which it has been applied. It is suggested that cyclohexylamine may also be used with advantage in high pressure hot water systems instead of caustic soda and also in low pressure hot water plants.

Nineteenth Annual Water Conference. Anon. *Combustion* 1959, **30** (Jan.) 43–7.

Abstracts of the papers and discussions are presented under the headings: 1. Sewage effluent (used in recirculating cooling systems and as boiler makeup); 2. Polymetallic cooling system treatment (corrosion problems and corrosion inhibitors); 3. Fundamental corrosion studies (on copper); 4. High speed demineralization (especially for nuclear reactors); 5. New ion exchange techniques (permitting increased flow rates); 6. Handling and feeding chemicals; 7. Field testing ion exchange; 8. Understanding ion exchange; 9 Russian practices.

Gas-Side Corrosion And Deposits

A Polarographic Study of the Corrosion of Iron and Some Ferrous Alloys by Sulfur Dioxide. F. J. Bowen and A. H. Gropp. *Corrosion* 1958, **14** (Dec.) 50–4.

Tests were made on one pure iron and seven low-alloy steels exposed to SO_2 over 12-hr periods and the results are presented in tables and graphs. A corrosion mechanism is proposed which involves the reduction of sulfurous acid by iron to the sulfide.

Unique Water-Table Solves Duct Design Problems. Anon. *Combustion* 1958, **30** (Nov.) 56.

The flow of gas in the precipitator and the ducts leading to and from it, is simulated on a water-table model with water dyed blue on to which aluminum powder has been sprinkled. The model represents only a vertical section of the precipitator, since the horizontal distribution of gas flow is considered to be generally uniform.

Tall Chimneys Beat the Smog. Anon. *Elect. Times* 1958, **134** (Dec. 11) 913.

An aerial investigation made during a heavy blanket of fog over London, has shown that the smoke plume from tall chimneys (300 ft) penetrates the fog layers at least 750 ft above ground level and then disperses normally, but that the plume from stations in which flue gases are washed is unable to do so.

Gaps in Our Knowledge on External Deposits and Corrosion in Boilers and Gas Turbines. *B. A. Landy. A.S.M.E. Preprint* 58-A-208 1958, (Dec.) 5 pp.

The problem of deposit formation and corrosion in boilers is reviewed and those phenomena pointed out, about which little or no information is available and further research should prove useful. It is believed that in addition to physical and chemical research, model work on aerodynamic flow of gases through boilers would assist in creating boiler designs in

which deposit formation would be much reduced; these studies should include admission of secondary and tertiary air at certain critical spots.

Practical Measures Against Gas-Side Corrosion of Boiler Tubes. M. Schulz. *Energie* 1959, **11** (Jan.) 2–12 (In German).

Severe erosion and corrosion leading to tube failure in a slagging furnace with fixed corner burners are reported and the measures tried and adopted to prevent further failures described. These included: 1. Increase of the velocity of the secondary air issuing from the lowest burner port; 2. Installation of baffles in the burners to increase the swirl of the coal-air mixture and to reduce the force of the jet and its deflection toward the furnace walls; 3. Enameling of the tubes in the most affected furnace zone having proved unsuccessful, the tubes were given an armor plating which gave longer but no lasting relief from attack; 4. Installation of new tubes with narrowly spaced studs sprayed with aluminum; lining of the front, rear and one side wall with chrome ore, and the other side wall with "vanalished" silicium carbide. The results of these latest measures are not yet available.

Flue Gas, Ash and Dust

Investigations Into Back-Discharge of Electrostatically Precipitated Dust. W. Simm. *Chem. Ing. Tech.* 1959, **31** (Jan.) 43–9 (In German).

The causes of low efficiency of precipitation of various dusts has been investigated experimentally. High restivity of the dust, high current density and small depth of the deposited layer of dust give rise to back ionization and are responsible for the low efficiency of electrostatic precipitation.

Use of Fly Ash in Concrete. C. T. Wanzer. COMBUSTION 1959, **30** (Feb.) 38–46.

After discussing the probable amount of fly ash produced in American power stations and the costs of its disposal, the favorable and unfavorable properties of fly ash for replacement of cement in concrete mixes are described. Fly ash has been used in one of the author's plant in the concrete mixes for three units under construction and a saving of $1.06 per cu yd was obtained. It is calculated that the whole of the fly ash produced in power stations could be utilized for concrete mixes with similar cost savings.

The Calculation of the Coefficient of Siegert's Equation for Solid Fuels and Fuel Oil. W. Buttner. *Energie* 1959, **11** (Jan.) 13–8 (In German).

The accuracy of the calculation of the flue gas loss by Siegert's equation (where the ultimate analysis of the fuel is not available) depends largely on the coefficient which varies with the fuel, the flue gas temperature, CO_2 content and combustibles in the ash. Nomograms are presented for estimating the value of the coefficient and equations are given for applying corrections. Examples illustrate their application for brown coals, bituminous coals, fuel oils and combined coal and oil firing.

Heat Recovery Plant

Shot Cleaning Its Development and Use for Cleaning Economisers, Tubular Air Heaters and Applicable Boiler Sections. R. E. Chappell and R. D. Meyer. *Combustion* 1958, **30** (Dec.) 39–45.

The three systems of shot cleaning, viz., light phase lift, pressure lift and hyperflow lift, and their range of application are described. At the Delaware station a light phase lift system was installed in September 1957 for cleaning tubular air heaters; the previously installed soot blowers had been unable to prevent clogging of the tubes and necessitated regular water washing. The shot cleaners have made possible continuous full load operation of the boiler without any loss of draught.

Indirect Preheating of Combustion Air. A. Upmalis. *BWK* 1958, **10**, (Dec.) 569–71.

In Scandinavian countries indirect air preheating has been successfully applied to avoid corrosion and clogging of air preheaters. In place of the air preheater a closed water circuit heated by flue gases and heating the air in a heat exchanger outside the boiler is used; where high air temperatures are required the water preheats the air before it enters the flue gas heated air preheater. Various possibilities are illustrated and the cost of direct and indirect air preheating compared.

Air-Cooled Heat Exchangers. E. C. Smith. *Chem. Engng.* 1958, **65** (Nov. 17) 145–50.

After briefly outlining the advantages of air cooled over water cooled heat exchangers, overall heat transfer, estimating methods, design and choice of fans are discussed.

Power Generation And Power Plant

Heat-Power Coupling for Different Thermal Power Generators. K. Winter. *Energie* 1958, **10** (Nov.) 471–4 (in German).

Recovery and utilization of waste heat from steam engines and turbines, gas and air turbines, internal combustion engines and combinations of gas and steam turbines and free piston gasifiers and gas turbines are discussed. It is shown that in most installations a recovery of 40–50 per cent of the heat input is possible by the heating of water to 160–195 F.

Heat and Power Generation in Public and Industrial Heat-Power Stations. Part IV. Actual Heat-Power and Heating Installations. T. Geissler. *Energie* 1958, **10** (Nov.) 444–53 (in German).

Examples of actual heat flow diagrams, boiler plants and heating installations are presented of: (1) Steam heating; (2) hot or warm water heating; (3) indirect hot or warm water heating; (4) heat-power stations with district heating by steam; (5) heat-power stations with district heating by hot or warm water; (6) large heat-power stations with preponderant electric power generation and warm water district heating; (7) extension of older heat-power stations by complete reconstruction or installation of a topping unit; (8) heat-power stations with flue gas heat condensate returned from the district heating system.

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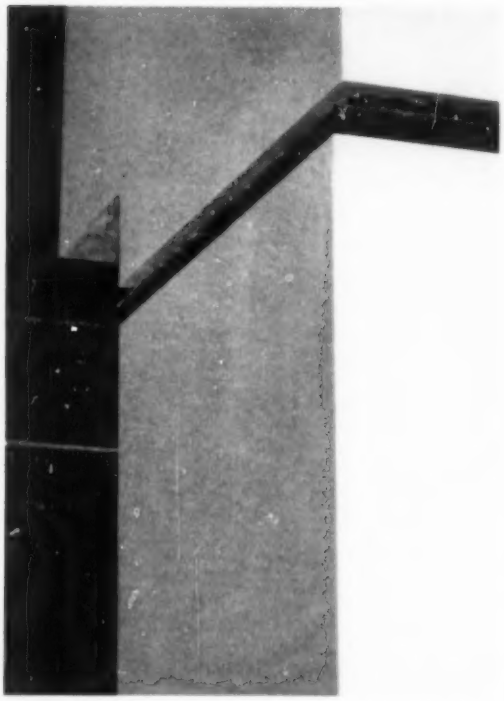

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Taking Load Off Public Power Stations by Industrial Heat Power Stations. R. Schlenk. *Energie* 1958, **10** (Nov.) 437–9 (in German).

It is argued that under the conditions existing in Austria it would be more economical for the government to help finance industrial heat-power stations and to reduce correspondingly the finance of public power stations. The former are able to generate electric power at a much lower price and, being sited at the center of consumption, would have negligible transmission costs. This presupposes, however, closer cooperation between the public and private power stations.

Comparison and Development Possibilities of Oil and Coal Fired Power Stations. O. Engler. *Energie* 1958, **10** (Nov.) 458–66 (in German).

The comparison of a 300 Mw oil and coal fired power station, assuming the same price of coal and oil on a C.V. basis, shows that the cost of a unit of electric power generated would be 5.5% lower with oil firing. In an actual installation, an oil fired boiler (385 klb/hr) without soot blowers and additives had an efficiency of 93% and no deposits or corrosion were found; this is believed due to the low furnace heat release rate. Combinations of free piston gasifiers, gas turbines and boilers are discussed, which would increase the thermal efficiency by about 5 per cent over that of conventional power stations.

Liquid Heat Storage for the Balancing of Steam Load Fluctuations in Industrial Plants. M. Stein. *Energie* 1958, **10** (Nov.) 477–81 (in German).

In works where hot water can be used for process and heating instead of steam, a balancing of steam flow fluctuations can be made simpler and cheaper by storage of hot water or a liquid heat transfer medium than by steam accumulators. Various examples are illustrated.

Generalized Steam Power Plant Heat Balance for Digital Computer Application. A. Labludowsky. *A.S.M.E. Preprint* No. 58-A-213 1958 (Dec.) 7 pp.

A method for solving a heat balance suitable for presenting to a digital computer is described and both its flexibility and limitation in handling the data are discussed.

Power Generation in the Iron and Steel Industry. C. Peschon. *Energie* 1958, **10** (Nov.) 485–8 (in German).

Because of the shortage of water the Arbed iron and steel works in Luxembourg have installed a combination of gas and steam turbines, which has

(*Continued on page 66*)

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(Continued from page 64)

proved most efficient and economic. The compressor of the gas turbine (5.4 MW) supplies compressed air to the gas turbine and the steel works. Exhaust gases are used to preheat the boiler feedwater (78 per cent) and as combustion air for the boiler (143 klb/hr). The 12.5 MW steam turbine has an extraction stage for process and heating steam, controlled as a function of the frequency of the network so that steam is taken only at low loads. Fluctuations in steam demand are evened out by steam storage. The condenser cooling water is air cooled and the boiler contains a blast furnace gas preheater in place of the air preheater. The average yearly heat rate is 11,500 Btu/kwhr and the thermal efficiency 27.45 per cent.

Get Top Performance from H-P Hot Water. R. N. Clarke and T. J. McMahon. *Power* 1958, **102** (Dec.) 110–1.

The Behr Manning Co. have extended their existing plant by the installation of a pulverized coal-fired LaMont boiler rated at 115 million Btu/hr at 150 psi and 365 F, and a 20,000 gal expansion tank. Fly ash is collected in a tubular dust separator and transported by a steam vacuum system to the ash silo. Combustion control is pneumatic, based on Btu output. Part of the hot water is used to generate steam for process and part is used directly for space heating. Secondary heat exchangers produce steam, hot water or hot oil for process. The advantage of hot water over steam is that each cu ft of pipe in the water system carries 18,610 Btu as compared with 434 Btu in a steam system, a ratio of 43:1. In addition, make-up required is only 0.1 per cent and the temperature drop over the whole length of piper run is so small that it cannot be measured.

Trends in Power Plant Design for Modern Paper Mills. T. J. Judge. *A.S.M.E. Preprint* No. 58-PWR-3 1958 (Sept.) 14 pp.

Following the trend toward larger manufacturing units, the boiler and turbogenerator capacities have also been increased in recent years, together with higher steam parameters. Examples of modern power plants for the paper industry are presented including sections through a typical bark burning boiler with combined oil and gas burners, cyclone fired boilers able to burn bark, coal, oil and gas in any combination and in capacities up to 750 klb/hr, 1450 psi and 1000 F, recovery boilers with outputs up to 300 kbl/hr, 1250 psi and 900 F. The problem of optimum extraction and exhaust pressure is also described.

Utility Boiler Fired with Delayed Coke and Coal. S. C. Brown. *A.S.M.E. Preprint* No. 58-FU-1 1958 (Oct.) 4 pp.

The American Oil Co. supplies the Virginia Electric and Power Co. with delayed coke and receives electric power in return. The C.E. controlled circulation steam generator rated at 1200 klb/hr has been specially designed to avoid difficulties when burning delayed coke averaging 3–12 per cent moisture, 10–20 per cent V.M., 2.9–5.4 per cent S, 0.048–0.053 per cent V and 3.8–9 per cent oil; the furnace heat release rate is 10 per cent lower than usual, use of nickel and molybdenum containing alloys have been avoided, Corten is used for ducts, air preheater rotor, cold elements and housing and the mechanical dust collector, and a steam-air preheater is installed to preheat the air to 250 F. Both superheater and reheater tube platens are widely spaced to avoid fouling. The bowl mills are oversize to allow for finer grinding of the coke. Difficulties experienced in handling the coke and firing it in a ratio of 50:50 with coal are described. Results of tests and continuous operation have been most satisfactory. The boiler has remained clean and wastage has been negligible. Wear of mill parts has not been excessive. No unusual corrosion or erosion has been found in the air heater, dust collector and fan ducts.

Comparative Data on the Total Cost of Generation of Conventional and Nuclear Power Stations. J. R. Finniecome. *Mech. World* 1958 **138** (Dec.) 534–6.

The comparison made for a 250 mw plant and an interest rate of 6 per cent shows the cost per kwhr to be 0.6521 d for nuclear and 0.654 d for a conventional station.

Packaged Air Preheater Cuts Fuel Costs, Improves Processes in Industry. C. L. Brown. *Pwr. Engrg.* 1959, **63** (Jan.) 82–4.

Packaged rotary preheaters are now available in U.S.A. for boilers with outputs from 25000–250000 lb/h. Their installation raises the efficiency by 5–6% if 6000 h of operation per year are assumed and by 13 per cent if 8000 h are assumed. A nomogram permits the rough calculation of the gross annual fuel savings for given conditions. Air preheaters may also be used to good effect in several industrial applications, examples of which are given.

Improved Design of Surface-Type Desuperheater. Anon. *Engineers' Digest* 1958, **19** (Dec.) 529–30.

The surface-type desuperheaters of hair-pin design installed at Awirs power station in Belgium showed cracks after some months of operation. Coils of different configuration were then installed but these, too, developed leaks after a short time. Finally, a design of straight concentric tubes was developed in which the tubes were able to expand and contract freely. These have given now trouble free service for many months.

Considerations on the Design of Graphite Heat Exchangers. A. Hilliard. *Brit. Chem. Engng.* 1959, **4** (Mar.) 138–43.

The design of "Polybloc" heat exchangers made of graphite elements is described. Its advantages are robustness, high erosion and corrosion resistance, freedom fron cemented joints and fluid tightness. Thermal conductivity, heat exchange efficiency and pressure drop are discussed and the results of tests given in graphs.

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forced Resin. J. C. Newson. *Engineer* 1959, **107** (Feb. 27) 343–5.

The use of reinforced resins for making condenser water boxes has been studied and the design developed from experimental investigations is described.

Condenser Tube Tests at Edge Moor Station Show High Heat Transfer for Stainless. Anon. *Power* 1959, **103** (Feb.) 75–7.

Because of rapid pitting, grooving and thinning of condenser tubes made of Admiralty material, half of the condenser tubes were replaced by stainless steel tubes. Subsequent tests showed that the heat transfer ratio of the stainless tubes was 90–96 per cent of the former tubes. The stainless steel tubes were also more resistant to corrosion and erosion and remained cleaner for a longer time.

The Application of Air Coolers in Industry. J. I. Krzymuski. *Ind. Chem.* 1959, **35** (Feb.) 63–9.

This review deals with the arrangement of tube bundles, the use of finned tubes, air fans, ducting, calculating of cooling surface, types of coolers, ground space requirements and economics.

Economic Consideration of Air-Cooled Heat Exchangers. G. Winters. *Brit. Chem. Engng.* 1959, **4** (Mar.) 144–7.
Design of Cooler Condensers. J. Madejski. *Brit. Chem. Engng.* 1959, **4** (Mar.) 148–53.

A mathematical analysis of the problem with a fully calculated example showing the application of the equations.

Nuclear Energy

Reactor Engineering. R. P. Kinsey. *Engineering* 1958, **186** (Dec. 5) 730–3.

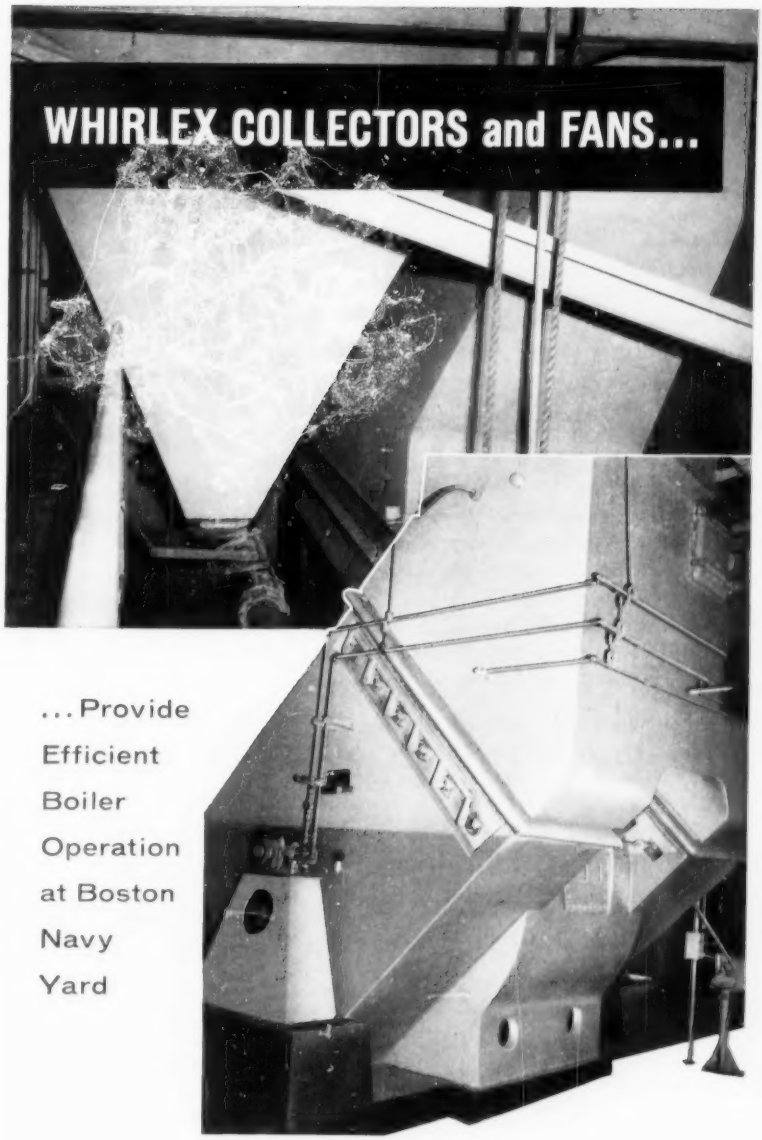
A review is presented of the papers submitted to the Geneva Conference dealing with the progress in design, design concepts, optimization, detailed core design and fuel element design.

The ORNL Conference on Gas-Cooled Reactors. Anon. *Nucl. Engng.* 1958 **3** (Dec.) 538–40.

A summary of the papers and discussion at the Oak Ridge National Laboratory Conference held on October 21 and 22, 1958, is given. Special attention is paid to the various proposals for fuel element composition and canning, coolant gases and reactor designs. A list of the papers is appended.

Pressure Tube Reactor Unlimited in Size. E. C. Fliss. *Elect. World* 1958, **150** (Dec. 8) 70–1.

(Continued on page 70)



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The expected results seemed sufficiently promising and it was decided to modernize the cleaning equipment of one boiler. The seven rotary blowers were replaced with four Diamond Long Retracting Blowers, one of which is shown below. This modernization proved to be justified as the boiler's maximum steam output was increased 11% and the exit gas temperature was reduced approximately 100° F.

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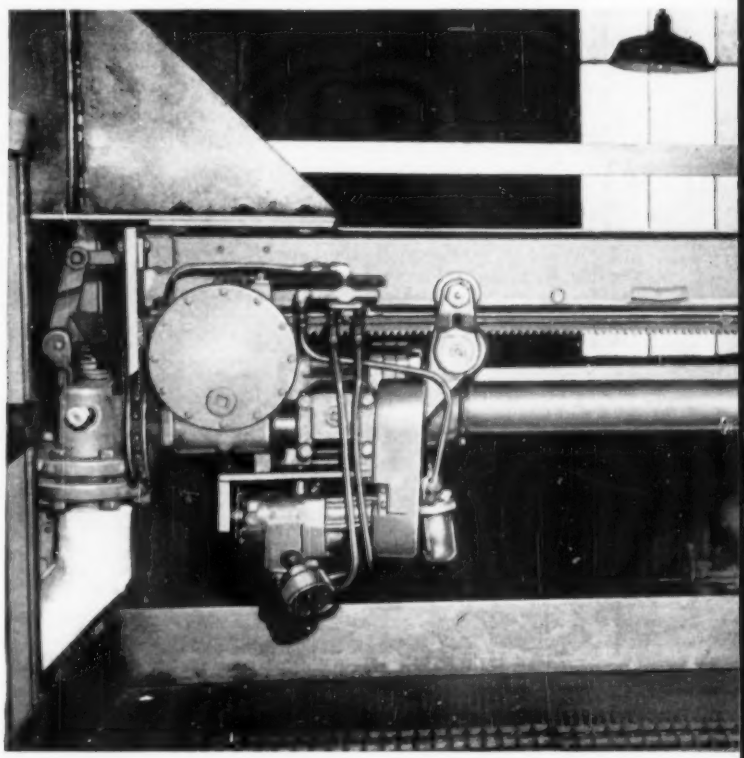

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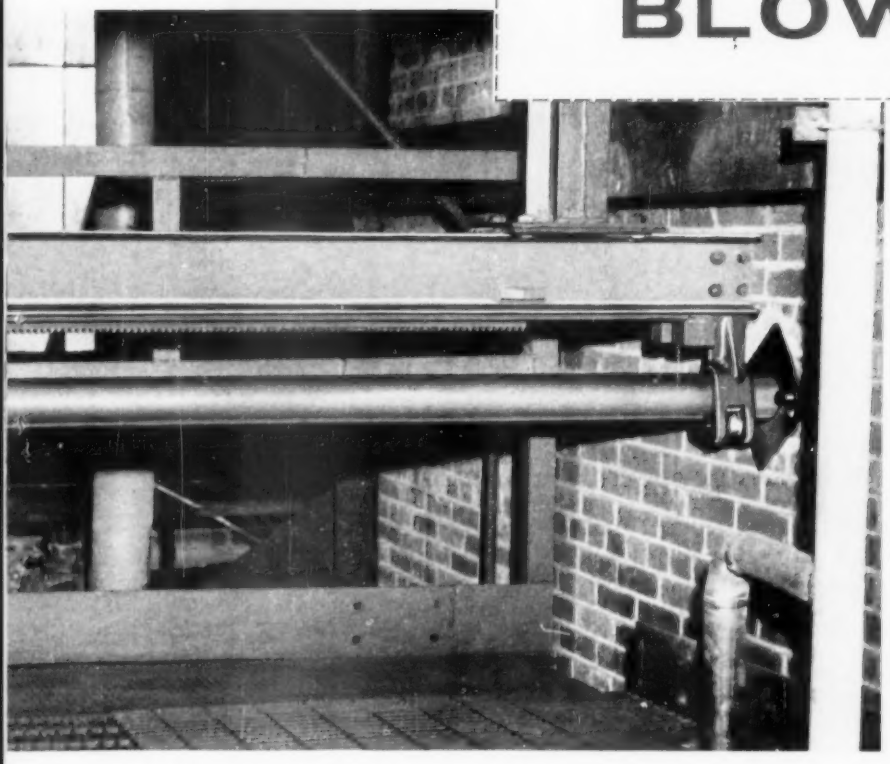

One of the four Diamond Long Retracting Blowers used to modernize the cleaning of the first boiler at the Ashland Works of ARMCO Steel Corporation. The results were so satisfactory that the three other boilers in this plant are now also being modernized.

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Abstracts From Technical Press

(Continued from page 67)

A prototype reactor of 19 mw gross electrical output is to be built which will contain pressure tube elements and heavy water as coolant and moderator. Tubes are of 3-in. diam and 18 ft length and contain 2 elements each of 19 zircaloy tubes filled with UO_2 pellets (2 per cent enriched). The burn-up rate should reach 8000 to 10,000 mwd/t. The core is surrounded by an Al tank with divider to separate moderator and reflector. The coolant flowing at a rate of 3.2 million lb/hr at a pressure of 1500 psi and an outlet temperature of 574 F will generate 203 klb/hr of steam at 700 psi to be heated to 725 F in an oil-fired superheater. The advantages of this pressure tube design are set out.

Instruments and Controls

A Survey of the Application of Automatic Devices for Electric Power Generation. A. C. Hartranft and F. H. Light. *A.S.M.E. Preprint* No. 58-AUT-3 1958 (Apr.) 8 pp.

Solves wet salt storage problems. New Morton LEVETROL Read all about it on page 77.

Developments in automatic data logging, load control, network analysis and improved control systems are discussed. A bibliography of papers published since 1950 is appended.

The Application of Computers to the Small Power Plant. E. S. Monroe. *A.S.M.E. Preprint* No. 58-A-230 1958 (Dec.) 7 pp.

The possibilities of using digital and analog computers for design, heat balance, cost accounting, power generation and consumption standards are analyzed. Emphasis is laid on the preparation of programs for determining the heat balance of a small steam, electric, refrigeration plant.

Miniature Controls Come of Age. A. L. Spaet. *Pwr. Engng.* 1958, **62** (Nov.) 73–5.

The reason for developing miniature instruments and controls, their design and application are discussed. Control systems not requiring special wiring by superimposing a high frequency signal on the normal frequency current and using radio transmitters and individually tuned receivers at each control point, pneumatic controls and prewired control assemblies are described.

Control Unit Finds Air Heater Hot Spots. E. N. Schwalje. *Elect. World* 1958, **150** (Nov. 17) 94.

The control unit mainly intended for oil fired boilers consists of a sensing element made of ceramic material enclosed in a 0.09-in. O.D. Inconel tube, in which two wires are embedded; the wires are connected to a Wheatstone bridge, alarm relay and potentiometer. The resistance of the ceramic material decreases exponentially with increase in temperature, permitting increased flow of current between the wires. Sensing elements are placed near the rotor at both ends of the air heater.

Grinding, Screening and Filtering

The Operation of P.F. Mills for Power Station Boilers. M. Robert. *Institut Francais des Combustibles et de l'Energie (Solid Fuel and Pulverised Fuel Conference 1957, Paper No. 4.05).*

An explanation is given of the functioning of mill installations supplying pulverized coal to power station boilers. Magnetic separation, feed, coal drying, particle size, control equipment, mill troubles, effect of dust, distillation, maintenance, noise, and determination of mill performance are covered. Various factors relating to the fuel, such as size, moisture content, chemical composition of the ash and Hardgrove index, are briefly considered.

From *C.E.G.B. Digest* 1958, **10** (Dec. 20) 3460.

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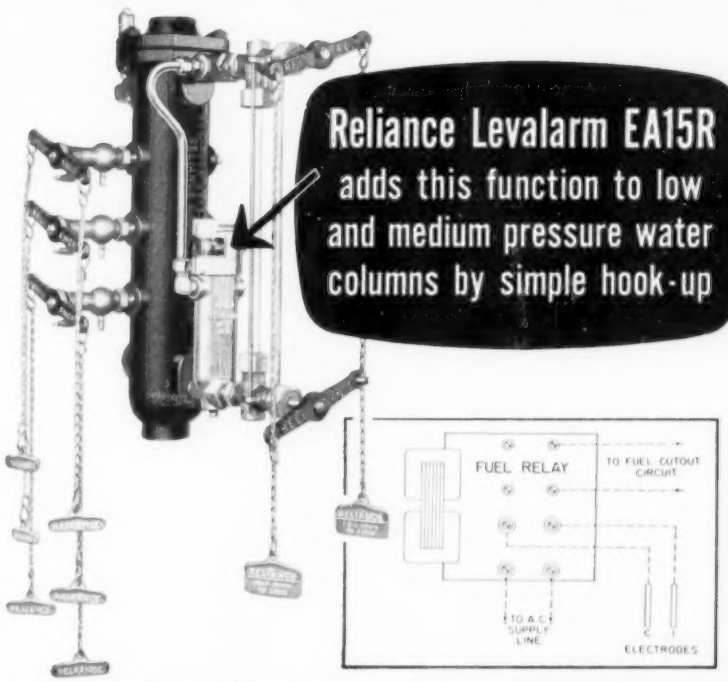
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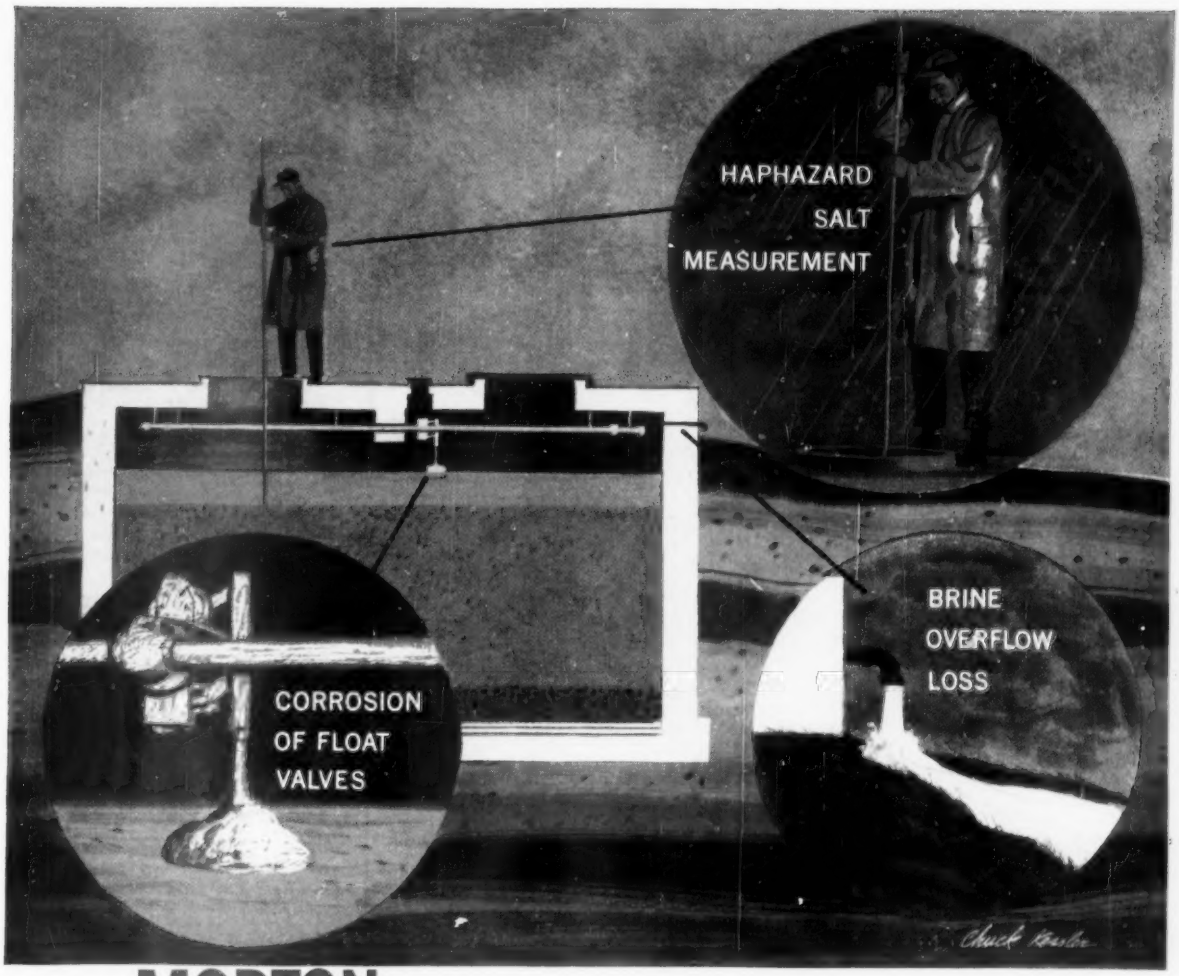

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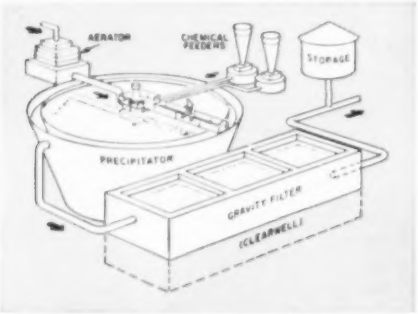
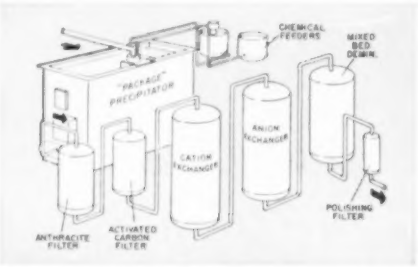
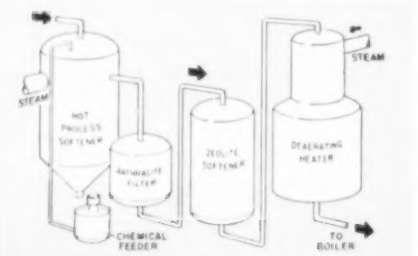


Well water for municipal supply. Aerator reduces CO_2 to reduce acidity, reduces taste and odor and oxidizes dissolved iron and manganese. Precipitator removes turbidity, color, hardness and oxidized iron and manganese. Gravity filters remove remaining traces of turbidity.



Process water for electronic components. Package Precipitator removes bulk of turbidity, hardness and iron. Anthracite filter removes remaining suspended matter. Activated carbon filter takes out color and absorbs dissolved organics. Demineralizer—cation, anion, and mixed bed—reduces dissolved solids to guaranteed maximum. Polishing filter removes traces of suspended matter.



Water for steam boiler. Hot process softener reduces hardness to a few grains per gallon. Also reduces silica. Anthracite filter removes remaining turbidity. Zeolite softener may be added to system where zero hardness is needed. Finally, the deaerating heater removes oxygen to prevent corrosion.

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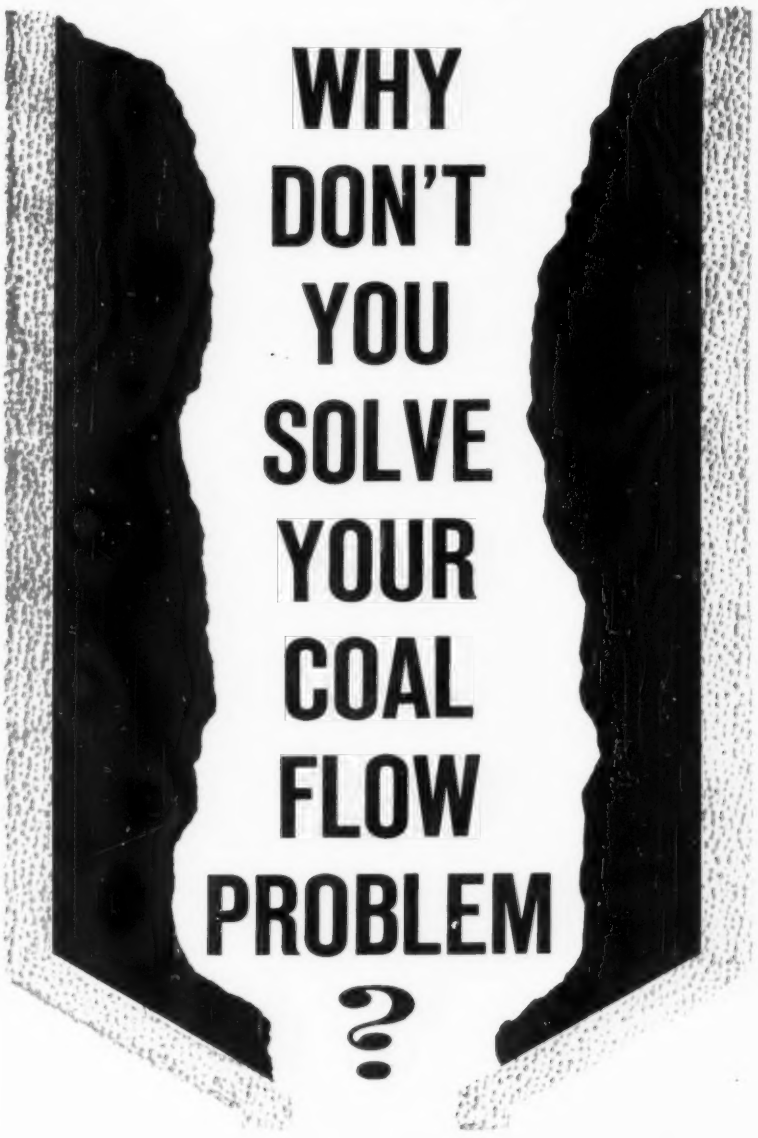

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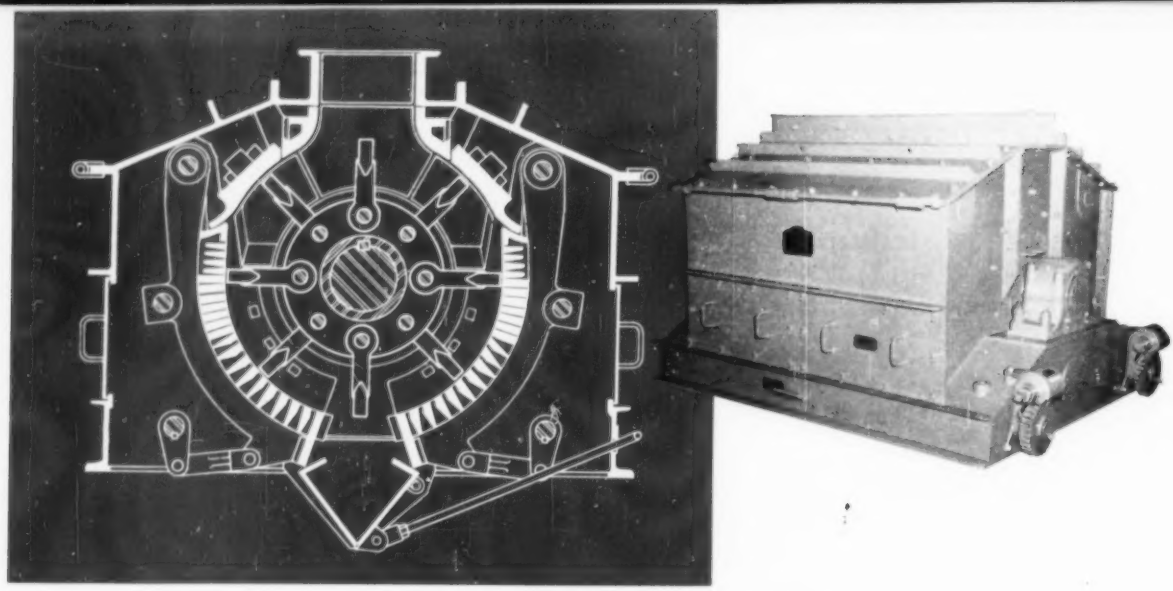

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Diamond Temperature Equalizing MULTI-PORT GAUGE*

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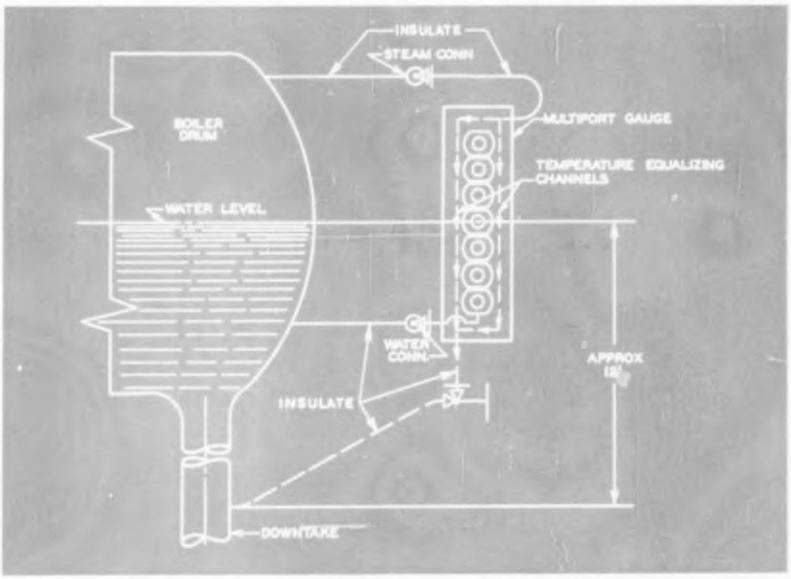

Diagramatic illustration of new Diamond Temperature-Equalizing Multi-Port Gauge installation.

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Gauge error (resulting from the gauge temperature being lower than boiler saturation temperature) is substantially avoided by introducing supplementary gauge heating in the form of steam condensing channels. These channels are parallel to the gauge water level channel as illustrated, and serve to heat the gauge level channel by direct conduction of heat from condensing steam through the gauge body itself. No external source of energy or control is required. The heating channels have a natural circulation system independent of the gauge level channel so that no faulty operation can occur under any circumstance.

Ask your local Diamond office or write directly to Lancaster, Ohio for Form 2150 for further information.

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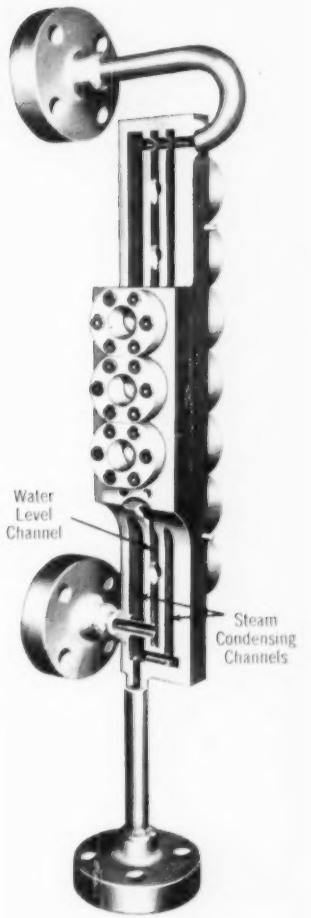

Cut away sections illustrate independent gauge body heating channels of the new Diamond Temperature Equalizing Multi-Port Gauge.

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